A UNITED STATES DEPARTMENT OF COMMERCE PUBLICATION

A11100 990069

NBS MONOGRAPH 131

NAT'L INST OF STANDARDS & TECH R.I.C.
A11100990069
Childs, Gregg E/Thermal conductivity of
QC100 .U556 V131;1973 C.2 NBS-PUB-C 1973

Thermal Conductivity of Solids At Room Temperature and Below

A Review and Compilation of the Literature

U.S. DEPARTMENT OF COMMERCE
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Thermal Conductivity of Solids At Room Temperature and Below

A Review and Compilation of the Literature

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Issued September 1973

Library of Congress Catalog Card Number: 72-600311
National Bureau of Standards Monograph 131
Supersedes NBS Circular 556
Nat. Bur. Stand. (U.S.), Monogr. 131, 624 pages (Sept. 1973)

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A Review and Compilation of the Literature

Gregg E. Childs, Lewis J. Ericks, and Robert L. Powell

An extensive compilation is given of the measured values of thermal conductivity for nearly all solid materials from room temperature down to 0.02 kelvin. The reviewed materials include elements, alloys and commercial metals, semiconductors, semimetals, ionic and valence crystals, minerals, molecular crystals, polymers, glasses, and disordered dielectrics. Excluded are foams, powders, earths, fibers, layers of composites, and similar other heterogeneous solids. Data for temperatures below 1 kelvin are presented separately. The tables and graphs are complete for literature references from 1900 to mid–1971. Experimental methods and physical phenomena are discussed in the text and coded in the tables for references for which curves are shown.

Key words: Alloys; commercial metals; cryogenics thermal conductivity; disordered dielectrics; elements; glass; ionic and valence crystals; minerals; molecular crystals; polymers; review semiconductors; semimetals; thermal conductivity.

1. Introduction

Experimental data on the thermal conductivity of solids at low temperatures have been compiled, evaluated, and summarized in tables and graphs. The temperature range of interest extends from about room temperature (300 kelvin) down to the lowest temperatures at which thermal conductivity experiments have been carried out, about 20 millikelvin. For convenience in analysis, we have classified the solids into seven groups: (1) elements, (2) alloys and commercial metals, (3) semiconductors and semimetals, (4) ionic and valence crystals and minerals, (5) molecular crystals, (6) polymers, and (7) glasses and disordered dielectrics. In addition there is a separate grouping of all materials for which there is published data below 1 kelvin. We have excluded many thermal insulating materials such as foams, powders, earths, fibers, and layers of composites.

This compilation is a revision and expansion of the NBS Circular published earlier [1].[1] For the previous Circular, the professional abstract and leading research journals were searched for references from 1900 to the spring of 1954. For this Monograph, publications from the same time period were searched again for additional references on dielectrics and other nonmetals; there was also a complete search of more recent references, publications dating from 1953 to the summer of 1971. A few references from later in 1971 and 1972 are included, but the coverage is not complete for this time period. Most of the references came from the leading research journals, but reports, industrial publications, and conference proceedings also contributed a few data curves and many tabular values. The most useful results from conferences came from the annual American Thermal Conductivity Conferences [2]. The main source of industrial data was the Alloy Digest [3]. The Cryogenic Data Center of the NBS Cryogenics Division also provided a computer search of all their collected references. Data from unpublished reports or proviate communications were not included unless there were no other data on the particular materials. Similarly, data obtained from indirect measurements, such as thermal diffusivity, were generally not included because of their much greater uncertainties. Very few references published before 1900 are included because of their generally poor material characterization and higher inaccuracies. Exceptions are made for those articles that contain values for materials not measured more recently and also for those publications considered to be especially important to development of experimental research on thermal conductivity.

[1] Figures in brackets indicate the literature references for the text. These references are to be found in section 2.4.

2. Discussion of Tables and Figures

2.1. General

The tables and figures for the materials have been arranged into eight groups, seven materials groups plus one group for experimental data below 1 kelvin. The groups are:

(1) Elements
(2) Alloys and Commercial Metals
(3) Semiconductors and Semimetals
(4) Ionic and Valence Crystals and Minerals
(5) Molecular Crystals
(6) Polymers
(7) Glasses and Disordered Dielectrics
(8) Very Low Temperature Data ($T < 1$ K).

The *Elements* are arranged by periodic groups, beginning with 1A and ending with the Lanthanide and Actinide series (see fig. 2.1.1). *Alloys, Semiconductors,* and *Ionic and Valance Crystals* are similarly arranged by their major component. *Copper* has an additional graph for physical imperfection effects; *silicon* and *germanium* have separate graphs for *n*- and *p*-type crystals; and *helium* has separate graphs for the isotopes He^3 and He^4. *Iron* alloys have been further divided into special types, with four separate tables for cast irons and carbon steels, stainless steels, and iron alloys and three graphs for face-centered cubic, body-centered cubic, and dilute body-centered cubic alloys. The classification criteria for the different iron alloy types are included in the main body of the tables, just before the first table on iron alloys. *Copper* alloys are divided into three types: regular, commercial coppers, and copper-nickel. The *valence* crystals diamond, sapphire, quartz, and garnet have been given special tables and graphs. Common and trade names [2] are included in graphs and tables for *glasses* and *polymers*. A list of code names for polymers, e.g., PE for polyethylene, is included in the polymer section of the tables.

In most cases the tables and figures for a particular material are on adjacent pages; however, sometimes graphs for a certain material are well separated from the appropriate tables when there is insufficient data to justify a separate graph. The tables are in proper order, nevertheless, and a note in the first column of the table indicates the appropriate graphs for each reference if the graphs are separated from the tables. In addition a note just below the heading of each table indicates the appropriate graphs for each material.

The temperature range for most of the graphs is from 4 to 300 kelvin, with arrows on the bottom of the graphs indicating the normal boiling points of liquid helium, hydrogen, and nitrogen and the melting point of ice. For materials where there is a lack of data over the whole range, or a large amount of data in a narrow range, graphs with special ranges are given, e.g., 1–10 K and 1–100 K. The very low temperature graphs cover the range from 0.1 to 1 K or 0.01 to 1 K.

Curves on the graphs have a code marking that indicates first, the last initials of the authors, second, the specimen number if more than one specimen by those authors is included on the graph, and third, the material if more than one type of material is included on the graph. The symbol(s) is included on the curve if the material is in the superconducting state and the relevant curves are drawn with a dotted line. Occasionally a letter or abbreviations are also enclosed in parentheses to indicate special physical treatments such as annealing or irradiation. An explanation of the code letters is included in the appropriate table for each material.

In many cases, not all specimens from a paper are shown in the appropriate graphs. Similarly, occasional data points are sometimes left off. Both of these omissions occur whenever the figures are becoming too crowded. Also, if only one or two experimental data points were reported, a curve is usually not given; the results are given only in the tables. If several authors report values that are nearly identical, the report that was published first is usually presented on the figure and the later report merely referenced in the tables. There are exceptions to this when the results of a later author are considered to be more accurate or extensive.

It cannot be emphasized too strongly that there is no meaning to "standard" or "recommended" curves or values for *pure metals* and *perfect dielectrics* at temperatures below their thermal conductivity maximum. Thermal conductivity values at the lower temperatures are completely dependent on the specific experimental specimen, its minor chemical impurities, and its physical defects. That is, the experimentally measured thermal conductivity for those materials at low temperatures is not an intrinsic property of the bulk material.

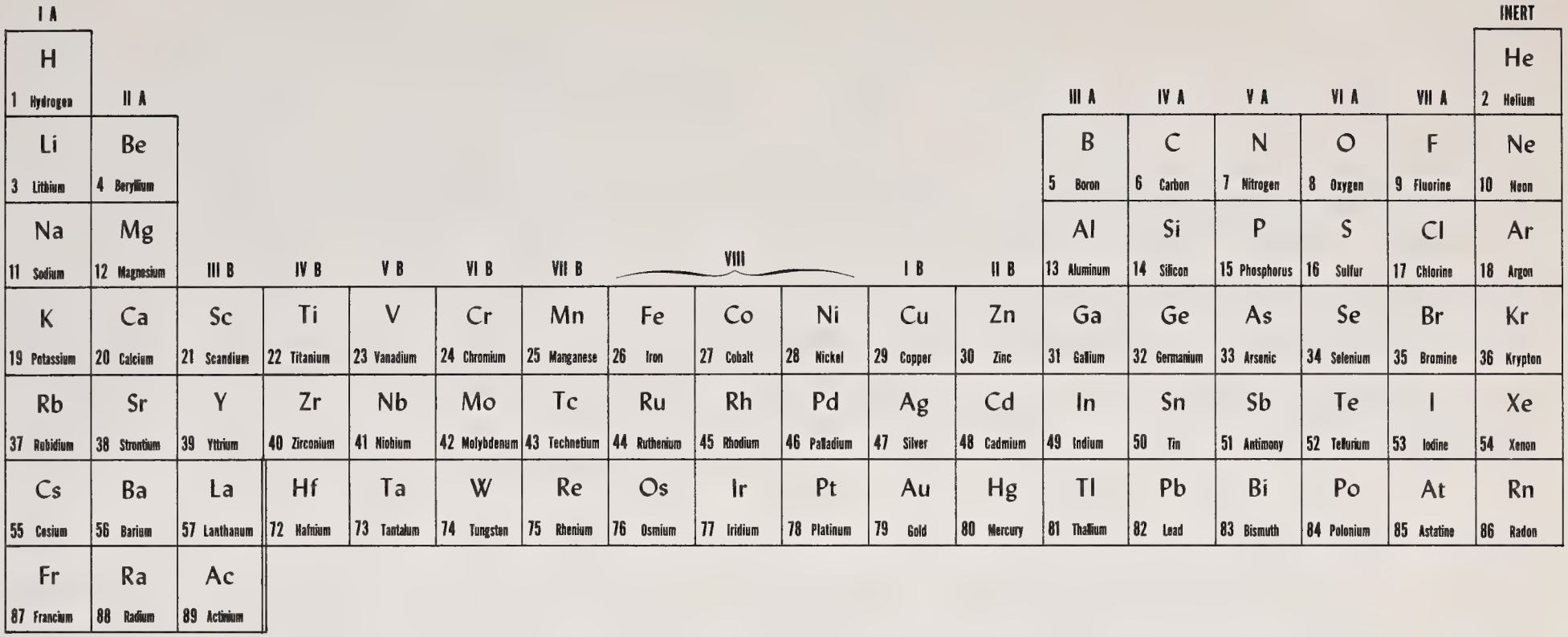
This review uses the units most often observed in thermal conductivity literature, that is, watts/centimeter-kelvin. Whenever the thermal conductivity values are very low, the units used in the graphs are milliwatts/centimeter-kelvin. The values quoted in the tables always have the same units as their respective graphs. Table 2.1.1 contains the factors for conversion of values into calories, British thermal units, and other less-often-used units.

Each of the materials tables is divided into five columns labeled: *Curve, Sample Source and Analysis* or *Composition (%), Remarks, Code,* and *Reference*. Explanations of the Code column are quite extensive; Codes A through G on Experimental Methods are described in section 2.2; Coles L through S on Physical Phenomena, in section 2.3. The other columns are explained below.

Within each table the references are arranged chronologically, except that all trade journal and handbook values are placed at the end of each material list. The first column, labeled *Curve,* is used as a locator for identifying the curve on a graph. If there are no letters in this column, no curve for that reference is included in the Monograph. In addition to letters indicating the author's last name, there are special notations for the number of the specimens, special heat or chemical treatments, state of superconductivity, and similar special characteristics. An explanation of any special note is included in the *Remarks* column whenever appropriate.

The second column indicates the *Sample Source* (whenever the information is available) and the *Analysis* (for elements) or *Composition* (for other materials). If the specimens were received from commercial firms, the source is indicated. If the specimens were prepared by the authors, no source is listed. The chemical impurities and composition are usually given in weight percent. Often, too often in fact, the references are very inadequate in providing characterization for their specimens. Such phrases as "pure" or "very pure" or, even worse, no comment at all are far too common. Two auxiliary methods of electronic characterization are quite valuable for metals and semiconductors; electrical residual resistance ratio (RRR) and carrier concentration, respectively. The residual resistance ratio is the

[2] Certain trade-names are identified in this paper in order to give a precise identification of the material measured. In no case does such identification imply recommendation or endorsement by the National Bureau of Standards.



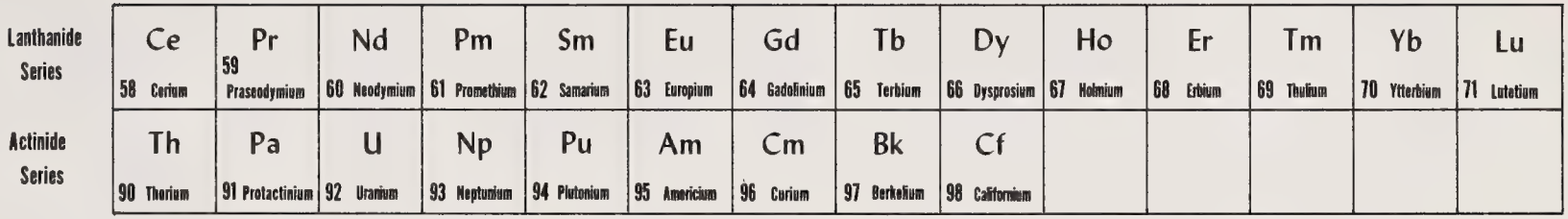


Figure 2.1.1. *Periodic table of the elements.*

Table 2.1.1. Conversion factors for thermal conductivity[a]

		$\frac{\text{Watt}}{\text{cm K}}$	$\frac{\text{Watt}}{\text{m K}}$	$\frac{\text{Watt in.}}{\text{in.}^2\ ^\circ\text{R}}$	$\frac{\text{Cal cm}}{\text{cm}^2\ \text{sec K}}$	$\frac{\text{Kcal m}}{\text{m}^2\ \text{hr K}}$	$\frac{\text{Cal in.}}{\text{in.}^2\ \text{sec}\ ^\circ\text{R}}$	$\frac{\text{Btu in.}}{\text{in.}^2\ \text{sec}\ ^\circ\text{R}}$	$\frac{\text{Btu in.}}{\text{in.}^2\ \text{hr}\ ^\circ\text{R}}$	$\frac{\text{Btu ft.}}{\text{ft}^2\ \text{hr}\ ^\circ\text{R}}$	$\frac{\text{Btu in.}}{\text{ft}^2\ \text{hr}\ ^\circ\text{R}}$
$\frac{\text{Watt}}{\text{cm K}}$	=	1.000	100.0	1.411	0.2390	86.04	0.3373	1.338×10^{-3}	4.818	57.82	693.8
$\frac{\text{Watt}}{\text{m K}}$	=	1.000×10^{-2}	1.000	1.411×10^{-2}	2.390×10^{-3}	0.8604	3.373×10^{-3}	1.338×10^{-5}	4.818×10^{-2}	0.5782	6.938
$\frac{\text{Watt in.}}{\text{in.}^2\ ^\circ\text{R}}$	=	0.7087	70.87	1.000	0.1694	60.97	0.2390	9.485×10^{-4}	3.414	40.97	491.7
$\frac{\text{Cal cm}}{\text{cm}^2\ \text{sec K}}$	=	4.184	418.4	5.904	1.000	360.0	1.411	5.600×10^{-3}	20.16	241.9	2.903
$\frac{\text{Kcal m}}{\text{m}^2\ \text{hr K}}$	=	1.162×10^{-2}	1.162	1.640×10^{-3}	2.778×10^{-3}	1.000	3.920×10^{-3}	1.555×10^{-5}	5.600×10^{-2}	0.6720	8.064
$\frac{\text{Cal in.}}{\text{in.}^2\ \text{sec}\ ^\circ\text{R}}$	=	2.965	296.5	4.184	0.7087	255.1	1.000	3.968×10^{-3}	14.29	171.4	2.057
$\frac{\text{Btu in.}}{\text{in.}^2\ \text{sec}\ ^\circ\text{R}}$	=	747.2	7.472×10^{-4}	1054	178.6	6.429×10^{-4}	252.0	1.000	3600	4.320×10^{-4}	5.184×10^{-5}
$\frac{\text{Btu in.}}{\text{in.}^2\ \text{hr}\ ^\circ\text{R}}$	=	0.2075	20.75	0.2929	4.961×10^{-2}	17.86	7.000×10^{-2}	2.778×10^{-4}	1.000	12.00	144.0
$\frac{\text{Btu ft.}}{\text{ft}^2\ \text{hr}\ ^\circ\text{R}}$	=	1.730×10^{-2}	1.730	2.441×10^{-2}	4.134×10^{-3}	1.488	5.833×10^{-3}	2.315×10^{-5}	8.333×10^{-2}	1.000	12.00
$\frac{\text{Btu in.}}{\text{ft}^2\ \text{hr}\ ^\circ\text{R}}$	=	1.441×10^{-3}	0.1441	2.034×10^{-3}	3.445×10^{-4}	0.1240	4.861×10^{-4}	1.929×10^{-6}	6.944×10^{-3}	8.333×10^{-2}	1.000

[a]Units are given in terms of (1) the absolute joule per second or watt, (2) the defined thermochemical calorie = 4.184 joules, or (3) the defined British thermal unit (Btu) where 1.8 Btu/lb = 1 cal/g and therefore 1 Btu = 1,054.35 joules.

ratio of the resistance at 0 °C to the residual electrical resistance (usually at 4 kelvin), $R_{0\ °C}/R_{4\ K}$. This ratio accurately reflects the degree of perfection of metallic specimens; the higher the ratio, the more perfect the specimen. Commercial metals have ratios from 2 to 10; moderately pure metals (0.01 at percent impurities) have ratios in the hundreds; for very pure metals (a few ppm impurities) the ratios may be in the thousands. The ratios reflect physical imperfections as well as chemical ones, but for common materials imperfections are dominant in increasing residual electrical resistance. In some instances, researchers use 298 K or other temperatures instead of 0 °C. for the upper temperature. In this compilation the upper reference temperature for the ratio is enclosed in parentheses if it is *not* 0 °C. The carrier concentration, either *n*, *p*, or net, is indicated for many semiconducting specimens. This concentration also reflects, for semiconductors, the influence of chemical imperfections or dopants.

Handbook and trade journal values quoted for commercial metals and alloys usually provide only nominal compositions; the actual compositions and thermal histories may vary within controlled limits (not noted in our composition column).

The third column, labeled *Remarks*, contains the information that we felt was necessary for interpreting the data or characterizing the specimens. The amount of information included in the *Remarks* column depended mainly on the thoroughness of each reference. There were extremes in characterization, with minimum characterization being much more frequent than the more desirable thorough discussion. Specifically, included in the column was information on the methods of preparation, mechanical treatment, thermal history, and auxiliary physical characterizations such as hardness. If the heat flow was significantly affected by boundary scattering (as it can be for pure valence crystals at very low temperatures) then the dimensions and surface conditions were noted. If the reference included important auxiliary tables or graphs on special thermal effects, influences of magnetic fields, separation of conduction mechanisms, etc., then such information was also mentioned as being included in the referenced paper. For commercial metals and alloys this column includes common code designations and trade names. Similarly, trade names are included for many of the polymers. Many of the measured specimens were single crystals; for those, information on the crystal orientation is included.

In several cases, not all available data are plotted in the graphs, in order to keep the figures from becoming too crowded. In such circumstances, the *Remarks* column indicates semiquantitatively where the curves would lie, e.g., 5 percent below a specific curve. When several authors report nearly identical values, the later references are usually given only in the tables.

The next to last column, *Code*, has a double letter-number code indicating information on the experimental methods used and on the physical phenomena observed, which are explained in detail in the next sections.

The last column, *References*, is self-explanatory. The bibliography at the end of the Monograph is arranged alphabetically by the name of the first author. Wherever there are multiple references by the same authors, the papers are listed chronologically with an (a), (b), or (c) as necessary if more than one paper was published in a given year.

2.2. Experimental Methods

Seven aspects of experimental thermal conductivity measurements have been selected for special consideration: (A) general method, (B) type of specimen, (C) gradient heater, (D) differential thermometer, (E) calibration or reference thermometers, (F) thermal isolation, and (G) estimated inaccuracy. The categories within each item are given in table 2.2.1. and are described in detail in this section. The information given is intended to only be a guide. As noted later, thorough discussions of special experimental methods have been given by some of the more experienced and careful experimentalists and reviews of methods are included in articles by White [4] (for low temperatures) and by Laubitz and McElroy [5] and several authors in reference [6] (room temperature and higher).

TABLE 2.2.1. *Code for experimental methods*

A. General method
1. linear heat flow (steady state)—vacuum
2. diffusivity—plate
3. diffusivity (pulse method; non steady-state) —rod
4. self-heating (Kohlrausch)
5. Forbes (linear heat flow with gas)
6. comparative
7. guarded flat plate or sphere
8. radial heat flow
9. indirectly from thermoelectric

B. Type of specimen
1. long cylinder
2. short cylinder (parallelepiped)
3. irregular
4. flat plate or sheet
5. wire
6. tube

C. Gradient heater
1. electrical heater
2. fluid heater or measured heat sink
3. self-heat by electrical current
4. irradiation heating
5. electromagnetic field

D. Differential thermometer (number of stations)
1. thermocouple
2. metal resistance thermometer
3. semiconductor resistance thermometer
4. gas
5. vapor pressure
6. susceptibility
7. liquid in glass

E. Calibration or reference thermometers

1. thermocouple
2. metal resistance thermometer
3. semiconductor resistance thermometer
4. gas
5. vapor pressure
6. susceptibility (paramagnetic salts)
7. mercury
8. assumed bath temperature

F. Thermal isolation

1. gradient shield and insulation
2. gradient shield only
3. isothermal shield and insulation
4. isothermal shield only
5. nothing

G. Estimated inaccuracy

1. <2%
2. 2–5%
3. >5%

A. General Method

The thermal conductivity of solid materials below 300 kelvin covers values over six orders of magnitude, as can be seen on figure 2.1.1. One may choose from several different experimental methods of measuring thermal conductivity. No one single method is suitable because of the large range of values encountered and the different types of materials measured. Of the nearly 600 references that were coded for general method, the steady-state linear heat flow method (A–1) was by far the most often used, being used in almost 84 percent of the papers. Five percent of the authors used the Kohlrausch method. The comparative, diffusivity (rod), guarded flat plate or sphere, Forbes, bar, radial heat flow, diffusivity (plate), and indirect thermoelectric methods are infrequently used. Data derived from the diffusivity and indirect thermoelectric methods were referenced only if there were no other data for the given material. The three most important basic methods will be briefly described. Similarities between the remaining methods will also be discussed.

1. *Linear heat flow*

The basic setup of this most common method assumes that the heat is conducted unidirectionally, usually along a rod of a uniform cross section. In figure 2.2.2. T_1 and T_2 represent temperature sensors, l is the distance between the temperature sensors, and A is the cross section of the specimen. The mean thermal conductivity is derived from the equation $\dot{Q}=K(T)\ \frac{A}{l}\ \Delta T$, presupposing there are no heat losses or generation along the length of the rod. The specimen is usually in the form of a rod whose form factor, l/A, is selected to allow accurate results for the particular type of material.

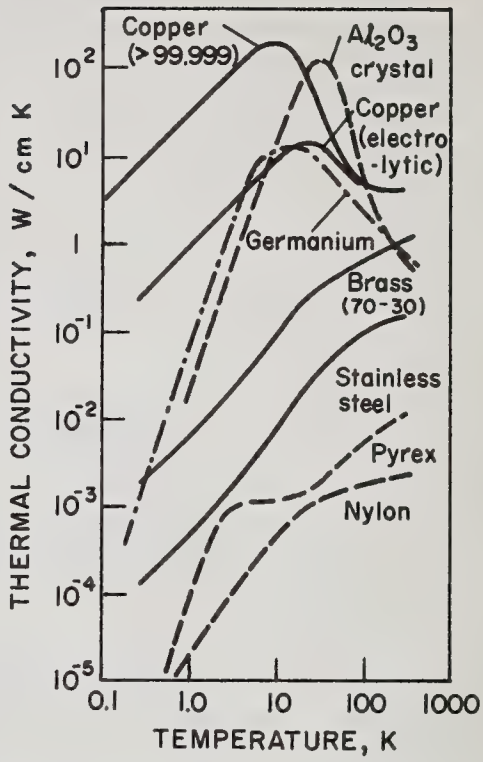


Figure 2.2.1. *Thermal conductivity variations of metals and alloys (_____), electrical insulators (– – –), and a semi-conductor (•—•—).*

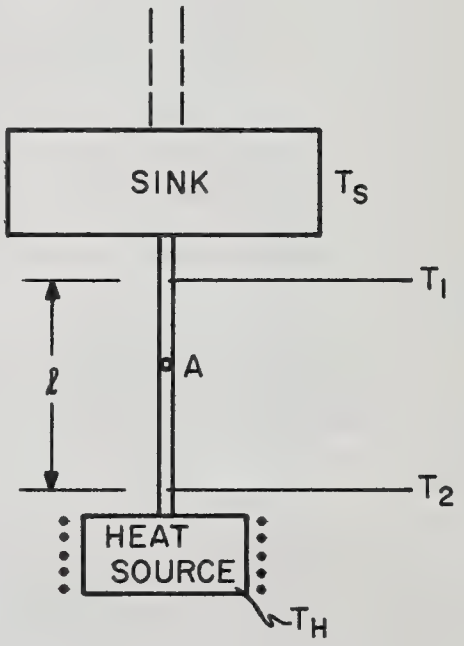


Figure 2.2.2. *Schematic for axial-flow steady-state measurements.*

In order to keep the heat flow, $\dot{Q}$, small enough for reasonable thermal stability and ΔA large enough to measure accurately, and yet small enough not to smooth out variations in thermal conductivity, the form factor must vary for different materials. For example, l/A may be as much as 1000 cm^{-1} for a pure metal, where the rod diameter may be one to two millimeters and length several centimeters; whereas for nonconducting materials, like glasses, diameters may reach 1 cm and l/A becomes less than 10. Good thermal stability and optimum temperature differences can be obtained when the product $K \cdot A$ has values near $0.1 \frac{\text{watt-cm}}{K}$.

A recent, accurate apparatus employing this method is described by Hust, Powell, and Weitzel [7] (see fig. 2.2.3). The specimens are about 23 cm in length. Liquid helium, liquid and solid hydrogen, liquid and solid nitrogen, solid carbon dioxide, and ice are all used to cool a heat sink thermally connected to a floating, controlled heat sink to which the specimens are attached. Surrounding the specimen is a controlled gradient thermal shield that eliminates radial heat transfer. The space between the specimen and the shield is filled with an insulating glass fiber that minimizes longitudinal radiative heat transfer. The apparatus is also nearly unique in having more than two temperature stations, thus allowing larger temperature spans to be covered with a single steady-state run.

For a description of other axial heat flow apparatus, especially those used for insulating crystals, see for example Holland and Rubin [8], Slack [9], and Klein and Caldwell [10]. The problem of measuring the conductivity of solidified gases by this method has been attacked successfully by Berman et al. [11], and others.

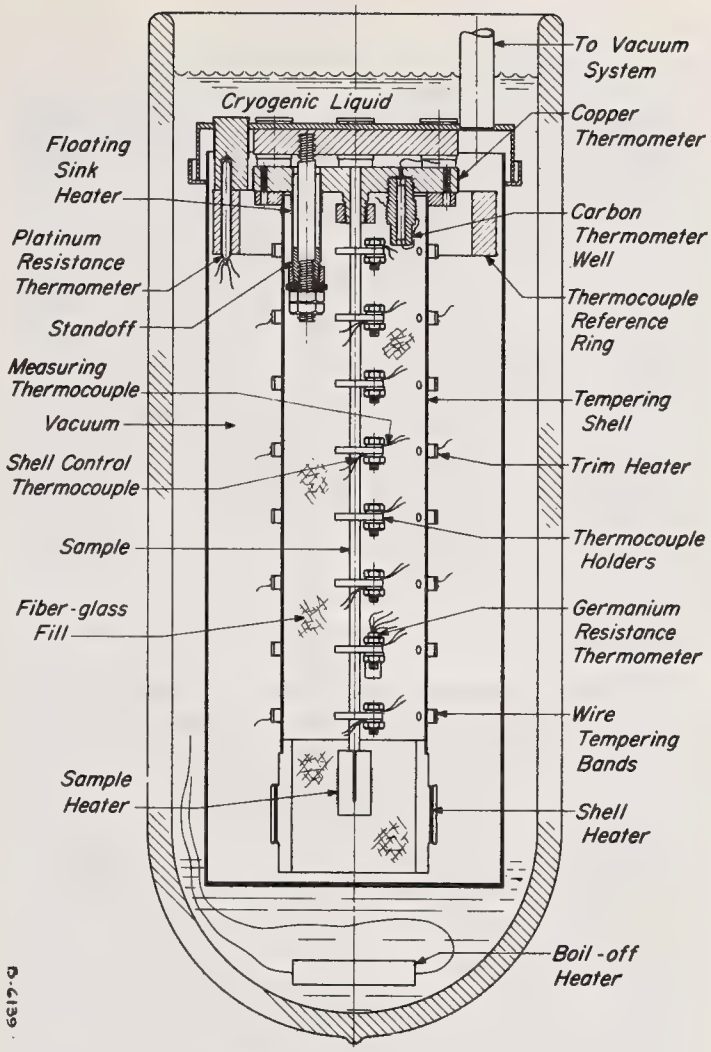


Figure 2.2.3. *The axial heat flow method of Hust, Powell, and Weitzel* [7].

2. and 3. *Diffusivity-plate* and *diffusivity-rod.*

Thermal conductivity values deduced from nonsteady state conditions are not common, but two methods do exist which use either a plate or a rod shaped specimen. In the pulse method, pulses of heat are applied to one specimen end or side, and the temperature along the specimen is measured as a function of time. The thermal conductivity can then be calculated from the thermal diffusivity equation if the specific heat is known. Morrison and Sturgess [12] supplied heat to their disk-shaped specimens by laser flashes. Daney [13] used a novel approach by measuring the one-dimensional freezing rate: the thermal conductivity of the solid can be calculated from the measured freezing rate and the applied temperature difference as a liquid near the triple point is frozen axially from one end.

4. *Self-heating (Kohlrausch)*

The self-heating (electrical heating) or Kohlrausch method relies upon the direct passage of an electric current through the specimen to supply thermal energy. The thermal conductivity may be calculated indirectly from the actual measurement of the electrical conductivity and temperature rise at various points on the specimen. The theory behind the method was developed by Kohlrausch [4] and by Jaeger and Diesselhorst [15] and is used more often at high, rather than low, temperatures. Jaeger and Diesselhorst [15] measured many materials at 291 K using this method. This method is difficult to use accurately if either the thermal or electrical conductivities vary significantly with temperature.

5. *Forbes*

The Forbes' method is similar to the linear heat flow method except that radial heat flow along the specimen is permitted and corrections and control experiments are applied to simulate the ideal axial heat flow conditions. Most of the measurements using the Forbes' bar method have been at temperatures above 300 K. The dual system used by Flynn and O'Hagan [16] can be used to make measurements by both the Forbes' bar and Kohlrausch methods. To measure the conductivity by a Forbes' technique, three sets of readings are often taken: an "isothermal" test to eliminate spurious heat flows, an "unmatched guard" test, and a "matched guard" test. Laubitz' [17] method for using the Forbes' bar technique, one of the most accurate, requires four sets of readings.

6. *Comparative*

This method sacrifices accuracy for simplicity in setup and ease of operation. The main difference between this and an absolute method is the way of determining the power entering the specimen. A material, known as a "standard," with a known thermal conductivity is used to determine the power input. The specimen of interest is placed next to, or in series with, the standard, and a determination of the different temperature gradients permits calculation of comparative thermal conductivity values. The experimentalist must be careful to insure that the conductivity mismatch between the specimen and standard is not too large. The interfacial resistance between the specimen and the standard, affecting the temperature distribution, is also important. R. W. Powell and Jolliffe [18] used this method to obtain rapid conductivity measurements of a number of materials.

7. *Guarded flat plate or sphere*

This method is used almost solely in the measurement of poor heat conductors, like plastics and solidified gases. The thermal conductivity of such materials is so low that potential heat losses in the apparatus are of major importance. Since the thermal conductivity of some of these insulating materials is influenced by pressure, the apparatus must allow for any possible changes in loading factor caused by thermal expansion or change of gas pressure. Conceptually this method is quite similar to the axial heat flow method, except that the form factor l/A is very much smaller and auxiliary heat losses tend to be much more important.

The apparatus by Black and Glaser [19] (see fig. 2.2.4) used the guarded cold plate method. The sample is located in an evacuated chamber between a hot plate and a double guarded cold plate. The hot plate can be maintained at any temperature between 77 and 500 K by circulating fluids, and the cold plate can have cryogenic fluids maintain a temperature between 20 and 243 K. Roder [20] used a flat-plate cell to measure the conductivity of solidified cryogens (see fig. 2.2.5). In his apparatus the liquid was placed under an appropriate pressure to maintain a solid sample several millimeters in thickness between the upper and lower plates.

8. *Radial heat flow*

Though very often used for high temperature measurements, the radial heat flow method has been used in only about one percent of the low temperature measurements. As in the axial heat flow methods, either absolute or comparative methods may be used. R. W. Powell [21] and his colleagues refined this method over many years (see fig. 2.2.6), and it is often used for measurements at room temperature and above. Disks stacked in the form of a cylindrical specimen have axial holes drilled through them to provide for thermocouple entry and positioning. The operating procedure is to move a thermocouple probe along the entire length of the stacked disks, adjusting the end guards to minimize axial temperature gradients. A disadvantage of this

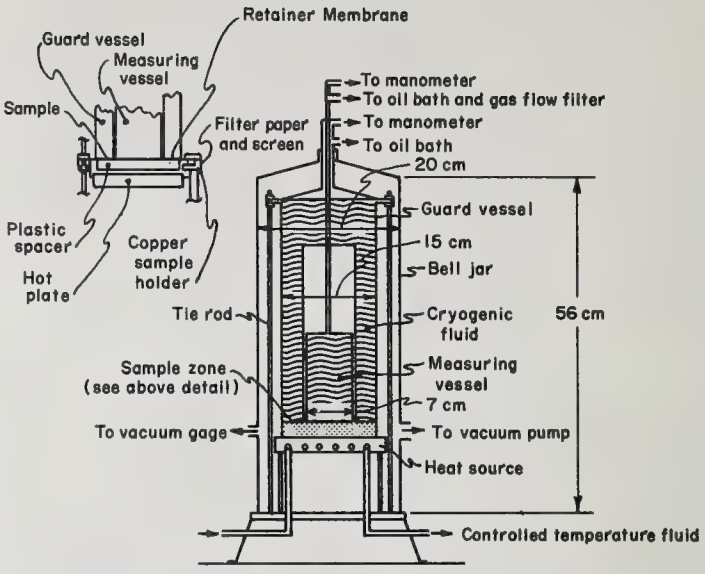


Figure 2.2.4. *The guarded cold plate method of Black and Glaser [19]*

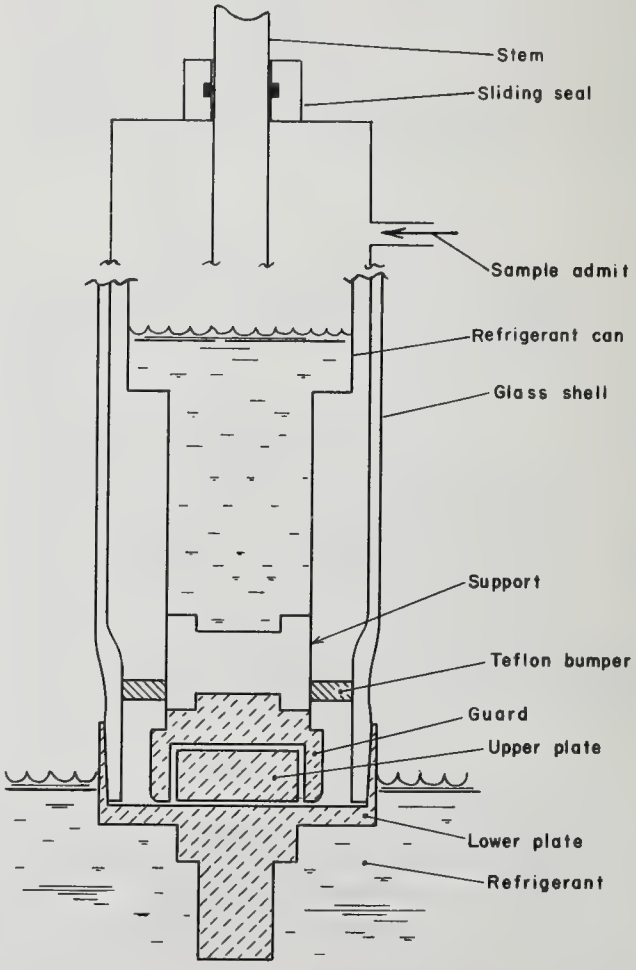


Figure 2.2.5. *The thermally guarded flat-plate cell of Roder [20].*

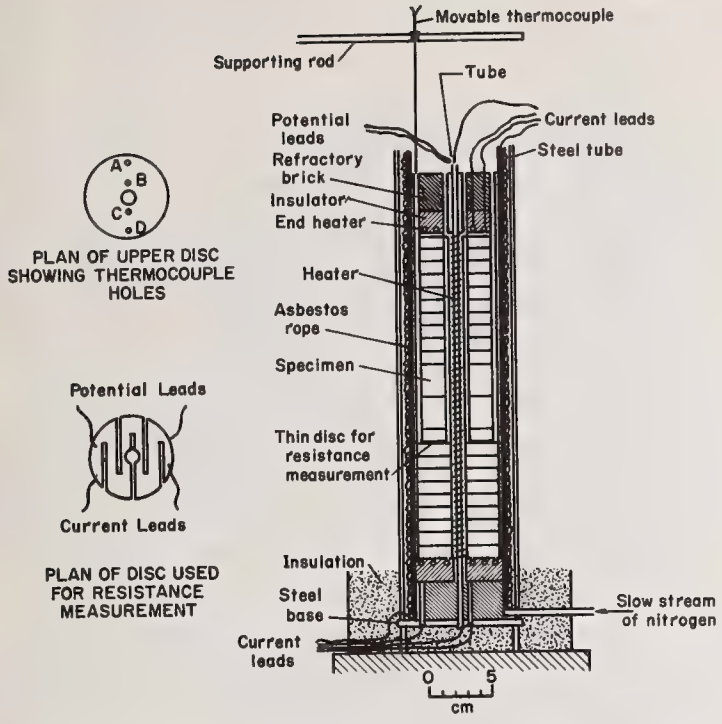


Figure 2.2.6. *The radial heat flow method of R. W. Powell* [21].

technique is the necessary wait for the system to reach equilibrium after each change in probe position. This apparatus allows the determination of electrical resistivity values simultaneously with thermal conductivity measurements. An apparatus developed at the Oak Ridge National Laboratory [5] avoids the problem of probe movement by having many thermocouples installed at various radial and axial positions. This method is especially useful for removing radiative losses for high emissivity, low conductivity specimens at high temperatures.

B. Type of Specimen

The type or shape of a specimen depends both upon the material and upon the method of measurement. The long cylinder shape was most often used, particularly with the linear heat flow method. Most cylinders varied in length between 1 or 2 and 30 cm and in diameter between 0.1 and 1 cm.

Other sample shapes also were used in several different methods and with specimens of unusual characteristics. The short cylinder, whose length and diameter were similar in size, was used mostly in the linear heat flow apparatus, although its use in a comparative system was mentioned often. Surprisingly, irregular shaped specimens were also occasionally used, especially for single crystals of semiconductors, ionic salts, or valence crystals. Flat plates of poor conductors like plastics or steels were used mostly in a guarded flat plate system. Wires of high purity metals, such as tungsten, copper, and platinum, were used in the Forbes, Kohlrausch, and linear heat flow methods.

C. Gradient Heater

In low temperature thermal conductivity measurements the most common means of creating the necessary flow of heat in a specimen was to use an electrical heater, but there are also several other means such as fluid heat exchangers, self-heating by an electrical current through the specimen, or heating by particle irradiation or alternating electromagnetic field.

An electrical heater was used in over 90 percent of the experiments coded in this study. The heater may be formed by winding a small coil of resistance wire directly to one end of the specimen. However, the most common method is to attach a coil of wire or a resistor to a small metal block which is in turn attached to the specimen. The heat losses by conduction along the lead wires and by radiation can become very significant and must be kept small relative to the heat conducted in the sample. Hust et al [7] have given a thorough discussion of the inaccuracies that may be caused by extraneous heat losses. Radiation losses become especially significant above 100 K.

Application of heat by a fluid heat exchanger was used in about 5 percent of the referenced papers. This type of heater is inherently less accurate than an electrical heater and, in addition, has the drawback of not being applicable over a wide temperature range. As an example, Wilkinson and Wilks [22] used liquid hydrogen between its triple point and normal boiling temperature to supply energy to a specimen which was refrigerated on the other end by boiling liquid helium.

Self-heating by an electrical current passing through the specimen, an integral part of the Kohlrausch method, was used in 5 percent of the reference papers. The sample must first of all be an electrical conductor to use this method. Among the first to use this method were Jaeger and Diesselhorst [15], who attached copper clamps to both ends of their specimen and applied a current of up to 350 A. In a novel experiment, O'Day [23] attached both ends of his U-shaped specimen to copper blocks through which an alternating current was supplied. Flynn [24] and Flynn and O'Hagan [16] have described the Kohlrausch method.

Heating by irradiation has been very seldom used. Vook [25], however, combined the conventional electrical heater method with heating caused by high energy electron-bombardment.

Heating by an alternating electromagnetic field is also very uncommon. Garrett [26] has described such a method that he used on a paramagnetic crystal. His specimen, a potassium chrome alum salt in the form of a long single crystal, was initially demagnetized from a uniform magnetic field, making its temperature uniform. Then a temperature gradient was established by applying a nonuniform magnetic field along the crystal axis; after a uniform temperature was attained, the magnetic field was removed, setting up a temperature gradient in the opposite direction.

D. Differential Thermometer

A variety of temperature measurement methods exist; while some are much better than others, each still

has special problems associated with it. The accuracy of a set of thermal conductivity data can often be estimated by finding out what type of thermometer was used in the experiment. At the same time, concern over whether absolute temperatures or temperature differences are important must be considered by the experimentalist. The number of thermometer stations attached to each specimen appears in parentheses in the code. Low-temperature thermometry has been discussed in books by White [27] and Scott [28].

1. *Thermocouple*

The most used method of temperature measurement was by thermocouples, quoted in nearly 50 percent of the methods. Many times an experimenter would use two, and perhaps three, sets of different thermometers to cover certain temperature ranges, and the thermocouples were usually included as one of the sets.

Thermocouples are a convenient size and have a short response time. They can be used over a large temperature range; Hust, Powell, and Weitzel [7] used ISA Type KP versus Au-Fe (Au—0.07 at. % Fe) thermocouples for measurement between 4 and 300 K. The number of stations used by experimenters varied between 2 and 15 (used by Laubitz and Cotnam [29] on their Ni-alloy specimen), with most experimenters using two or three stations.

2. and 3. *Metal resistance* and *semiconductor resistance thermometers*

Electrical resistance is a characteristic that is measured easily and it is quite reproducible. A metal resistance thermometer, of which platinum is the most commonly used, can be used with good results down to 10 K; below 10 K impurity scattering causes the electrical resistance to become relatively insensitive to temperature. Thermometers of good quality are obtainable from commercial sources, or they can be made in the laboratory. Standard equations and interpolation formulas given in the IPTS (1968) are used to specify the resistance/temperature relation for platinum thermometers.

Semiconductor resistance thermometers provide good sensitivity at the lower temperatures. Carbon thermometers can be made from commercial radio resistors, and colloidal suspensions of graphite painted on a substrate will make a carbon film. The instability on thermal cycling is the major drawback. Sharma [30] used two carbon resistors to measure the temperature gradient along his specimens down to 0.4 K. Germanium and silicon semiconductors are completely reproducible and also make good thermometers below 60 K for measuring absolute temperatures and temperature differences.

Of the various resistive-type thermometers, carbon films are most convenient to use below 0.5 K; bulk carbon or germanium, from there up to 60 K; and platinum, from 20 K to room temperature.

4. *Gas*

The relative ease of calibrating gas themometers, especially for differential measurements, combined with an earlier lack of standardized thermocouples or germanium thermometers, led to the use of gas thermometers by 15 percent of the referenced authors. They have been used by deHaas and Rademakers [31], White [32], and Rosenberg [33] between 2 and 200 K. They are independent of magnetic fields and can be directly read from pressure gages and differential transducers, and they can give results in terms of absolute temperature or adapted to differential thermometry. A good discussion on gas thermometer construction and different setups appears in White [27].

Construction of gas thermometers depends upon bulbs of certain size that are filled with gas at an adjustable pressure. Corrections for differences in temperature distribution along the gas inlet tubes are difficult but necessary. Bulb pressure can be adjusted to provide high-accuracy response in different temperature regions.

Since 1960, use of gas thermometers has dropped off because of availability of reliable thermocouple and germanium thermometers.

5. *Vapor pressure*

Vapor pressure thermometers usually indicate the vapor pressure of the system refrigerants. The vapor pressures of liquid helium, hydrogen, oxygen, and nitrogen have been tabulated in easily obtained references. Corrections are required for: slight impurities like oxygen in the system, temperature difference between the barometric column and the standard column, and slight gravity differences. Again, White [27] has a good discussion on this method of measurement. Their main disadvantage is, of course, their limited temperature ranges.

6. *Susceptibility*

Few systems have used magnetic susceptibility thermometers. Their usefulness exists primarily at low temperatures, around and below 1 K, although they have been used as high as 30 K. The susceptibilities of some paramagnetic substances follow the "ideal" Curie or Curie-Weiss laws close enough to allow accurate thermometry. Bijl [34] discusses magnetic thermometry along with his conductivity measurements on chromium potassium alum. Important problems encountered below 0.3 K for most of these thermometers are the nonideality when the interaction energy between paramagnetic spins become comparable with the total energy, and the measured magnetic temperature begins to depart from the true thermodynamic temperature.

7. *Liquid in glass*

This very old thermometry method was outdated for thermal conductivity measurements after 1900. One of

the last to use this type of thermometer was Lorenz [35], who used a set of nine in his Forbes' bar apparatus.

E. Calibration or Reference Thermometers

Although the existence of a calibration or reference thermometer within an experimental apparatus is important, a large number of the authors felt it unimportant to make mention of it. Less than 50 percent of the referenced papers reported their method of calibration for their gradient thermometers. One-third of those reporting specific types of calibration thermometers used a vapor pressure thermometer; twenty percent, a referenced thermocouple; twenty percent, a gas thermometer, ten percent, a metal-resistance thermometer; the other methods were each used less than ten percent of the time.

The mechanics of a calibration or reference thermometer is identical to those thermometers used to measure a temperature gradient. However, the main purpose of these thermometers is to act as a calibration point or absolute temperature reference for those gradient thermometers. These thermometers are stationed usually near the top of the cryostat in which the specimen is held.

Similar to the gradient thermometer, the specific calibration thermometer is usually better in one temperature range. For this reason many of those authors who indicated their calibration method actually used two or more calibration or reference thermometers. And usually the calibration thermometer was of a different type from the gradient thermometer used in the same apparatus. Often the gradient thermometers were calibrated in other apparatus prior to installation in the thermal conductivity apparatus.

F. Thermal Isolation

Factors such as gas conduction, wire conduction, and radiation can lead to significant systematic errors in the experimental determinations. Gas conduction errors can be significantly reduced by evacuating the system to at least 10^{-5} mm Hg. Several different methods of treating heat losses by lead wire conduction and radiation involve surrounding the specimen with a thermal shield, which is usually isothermal. To make the shielding more effective, the bottom, middle, and top of the shield should be held at approximately the same temperature as the specimen at the corresponding position.

An isothermal shield simply surrounding the specimen can be a piece of aluminum foil (Klein and Caldwell [36]) or a copper radiation shield (Rosenberg [33]). More elaborate is the shield used by R. Berman [37] where it is made in three sections. The base is hard soldered to one section which is also permanently attached to the collar around the heat sink. The other two sections are put in position after the specimen has been mounted and are soldered to the top and to the bottom of the chamber. The sections of the radiation shield are not soldered to one another so that the gas pressure inside the shield is the same as that inside the surrounding vacuum jacket. The edges of the sections overlap, however, so that no radiation reaches the specimen from outside the shield. The method of surrounding the specimen with just an isothermal shield was used by over three-fourths of those who described their experimental apparatus.

A gradient shield is a considerable improvement over an isothermal shield since heat losses by radiation are further cut. The gradient shield used by R. L. Powell and co-workers [38] has a copper fastening ring at the top to provide a good thermal contact to the heat sink when the shield is bolted in place. The bottom is also made of copper to provide a nearly isothermal region surrounding the specimen heater. The longer intermediate section of the shield is made of thin stainless steel to reduce the power input necessary to maintain any given temperature gradient. Three heaters, located at the bottom, midpoint, and near the top, are wrapped on the shield to supply power necessary to maintain this proper thermal gradient. The temperature difference between the specimen and a horizontally opposed point on the shield is measured by differential thermocouples. Heaters on the shield bring about thermal balance between the shield and the specimen. Also, this shield is split vertically in two, to allow rotation of the front half during mounting and assembling of the specimen. The two halves are bolted together near the top, and a copper bar is soldered across the bottom to improve thermal contact.

In both cases, with either the isothermal or gradient shield, either the space between the shield and specimen can be left vacant, or the specimen can be surrounded by a powder or fiber insulation to further reduce a heat loss. However, there can be significant longitudinal radiative losses, even with a gradient shield, if there is no radiative insulation between the specimen and the shield. It is important to recognize the possibility of the surrounding insulation acting as a heat-shunt to the specimen. The heat that supports the longitudinal temperature gradient in the insulation adjacent to the specimen comes from the specimen and, if not corrected for, will lead to high conductivity values. Hust and co-workers [7] used glass fiber radiation shielding around the specimen necessary for extending the measurements above 120 K.

G. Estimated Inaccuracy

The most exact and quantitative specification for experimental method coding should be the estimated inaccuracy, but it is just the opposite. The total uncertainty for thermal conductivity values consists of contributions from systematic bias, experimental imprecision, material variability, and mathematical analysis errors. In nearly all experimental reports the quoted inaccuracy only refers to the experimental imprecision component, and even that is usually overoptimistic. Errors caused by systematic bias and material variability are nearly always much greater than those due to experimental imprecision. We estimated the total imprecision in a relatively subjective manner, but as fairly as we could. In making this estimate, many considerations were kept in mind, including specimen size

and characterization, experimental method, analysis method, temperature range, thermal shielding control experiments (nearly always absent), and comparisons to other experiments. Very seldom is the true inaccuracy or uncertainty less than 2 percent! Two recent papers have given a good discussion of systematic experimental errors and their analysis, Laubitz and McElroy [5], and Hust et al. [7].

2.3. Physical Phenomena

A majority of the thermal conductivity measurements were made in order to elucidate one physical phenomenon or another, rather than to merely obtain handbook data. Even then, most of the research reports that emphasized design data also included significant discussions on interpretation of physical mechanisms for heat transport. We have therefore included in the coding a large number of designations for the different effects. Generally speaking we coded directly from the auhors' discussions and did not analyze the reported measurements. There were exceptions: in some reports the particular phenomena were clearly there, but not noted by the author; in others, the authors were clearly mistaken in their interpretations or included unwarranted analyses based on experimental errors.

The best general discussions of thermal conductivity theory have been given by Klemens [39], Rosenberg [40], and Ziman [41]. Because those references are so good for the general concepts we will not include a detailed theoretical discussion of the various physical phenomena and interactions. In addition to the general book references listed above, most experimental papers will reference the best theoretical papers on each phenomenon.

Because much of the interest in thermal conductivity is directed toward metals and alloys, we include a brief conceptual description of conduction mechanisms in those solids. With even a brief glance, it is easy to see that there are extreme variations in both the amplitudes and the temperature dependencies. There is however an order within the varity of values and it is possible to interpret, or even predict, values if one properly utilizes knowledge of the fundamental phenomena.

Two parallel interdependent mechanisms are primarily responsible for the transport of heat in a metal at low temperatures. The first and most important is the electronic thermal conduction, the transport of thermal energy by the motion of conduction electrons. The second is the lattice thermal conduction, heat transport by directional cooperative quantized vibrations (called phonons) of the thermally excited interacting lattice ions. These are the same phonons that are responsible for the observed specific heats and thermal expansions in metals. For pure metals and dilute alloys, the lattice thermal conductivity is very much smaller than the electronic thermal conductivity. For alloys with several percent, or more, of additives, the decreased electronic thermal conductivity allows the lattice contribution to become significant, though it is still small compared to the electronic contribution. For most metals and alloys, the total conductivity, K, is the sum of two terms, the electronic conductivity, K_e, and the lattice conductivity, K_g (the subscript g stands for Gitter, the German word for lattice); that is, $K = K_e + K_g$. This equation is analogous to the one used in electrical circuit theory for the total conductance of two conductances in parallel. Both conduction mechanisms, K_e and K_g, are limited by various scattering processes, each process acting additively as a separate resistance in series. A representation of the analog is given in figure 2.3.1.

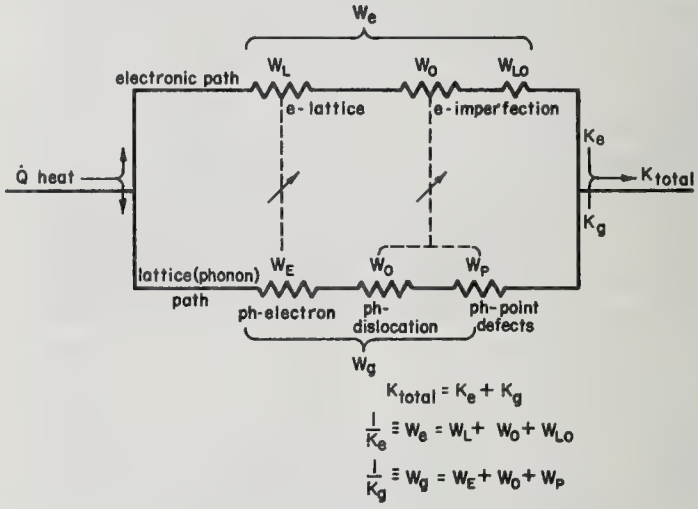


Figure 2.3.1. *Electrical analog for thermal conduction.* (The dashed lines with arrows indicate resistance that depend on the same basic scattering phenomena.)

There are two main scattering processes that limit the electronic conductivity in the above expression. The first is the scattering of conduction electrons by thermal vibrations of the lattice (the phonons again), as represented by the electron-phonon resistivity, W_L, a characteristic property for a given metal. This scattering is most important at intermediate temperatures (about 40 to 80 K) and higher. Various aspects of the electron-phonon interactions are coded with the letter L. The second process is the scattering of conduction electrons by imperfections (both impurity atoms and lattice defects), as represented by the electron-defect resistivity, W_O. This scattering is most important at the lower temperatures. Electron-imperfection interactions are coded under the letter M in general; however, some special effects such as magnetic field dependence are included under N. The reciprocal of the total electronic thermal conductivity, K_e, is the total electronic thermal resistivity, W_e, which is assumed to be the sum of the two resistivities, W_L and W_O, plus a small deviation term, W_{LO}; that is, $1/K_e \equiv W_e = W_L + W_O + W_{LO}$. This equation is analogous to the one used in electrical circuit theory for the total resistance of resistances in series.

The deviation term has been studied theoretically by Kohler [42] and independently in experiments by Powell et al. [43]. It is of the form: $W_{LO} = \alpha W_L W_O / (\beta W_L + \gamma W_O)$, where α, β, and γ are constants of

Order 1 and can be determined experimentally. Though theoretically significant, the term is numerically important only for very pure metals. This effect is coded under N–1.

Whenever the interaction term W_{LO} is negligible, the thermal equivalent of Matthiessen's rule for electrical resistivity, $W_e = W_L + W_O$, is approximately correct. A graph of this relation and its equivalent for conductivity are given in figure 2.3.2. With knowledge of the two separate terms, prediction of the total electronic thermal resistivity becomes reasonable.

Both theoretical and experimental research have led to expressions for magnitudes and temperature dependences of the electron-phonon and electron-defect resistivities:
$W_L = AT^n$ ($n \approx 2$ to 3, $T < 40$ K); $W_L \approx$ a constant (near room temperatures); $W_O = B/T$ (at all temperatures). The constant A in the electron-phonon resistivity term is related to the intrinsic properties (including the characteristic temperature, θ) of a given metal and will not change for minor additions of chemical impurities or physical imperfections. The constant B in the electron-defect resistivity term is related to the given amount of imperfections and residual electrical resistivity of the specific specimen. Above 100 K, the electron-phonon resistivity approaches a constant value, often labeled $W\infty$.

The shapes of the curves for aluminums in figure 24a in the main set of graphs are typical of pure metals: electronic thermal conductivity is predominant and lattice thermal conductivity is negligible. For a metal specimen with no chemical impurities or physical defects, the electron-phonon scattering component caused by the thermally excited ionic lattice, W_L, governs the temperature dependence of the conductivity.

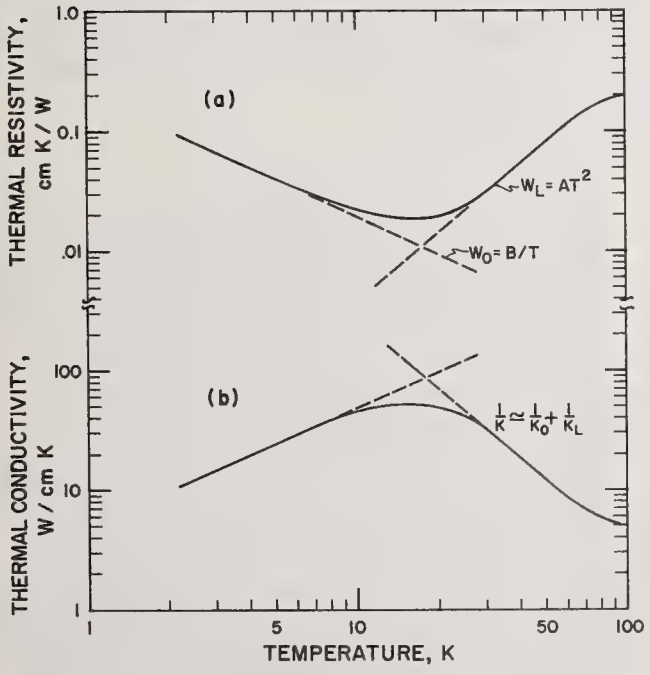


Figure 2.3.2. *Matthiessen's rule for thermal resistivity (a) and thermal conductivity (b) of copper.*

As the temperature is lowered, the electronic thermal resistivity decreases approximately proportionally to T^2; the thermal conductivity rises equivalently. Superimposed on this decreasing ideal electron-phonon resistivity is the electron-defect resistivity which increases as the temperature is decreased. At a minimum in the thermal resistivity curve or maximum in the conductivity curve, the two scattering mechanisms are approximately equal. At higher temperatures, electron-phonon scattering is predominant; at lower temperatures, electron-defect scattering is predominant. The defects that limit thermal conductivity at low temperatures can be quite varied: chemical impurities, inclusions, vacancies, interstitial atoms, dislocations, grain boundaries, external surface boundaries, and so on. Fortunately, for all but the surface boundaries the scattering resistivity has the same temperature dependence, the B/T mentioned earlier. The boundary scattering is difficult to investigate and can be observed only in extremely pure metals at very low temperatures.

At the present, it is not possible to predict accurately the thermal conductivity of pure metals on the sole basis of their chemical analyses or physical specifications. The effect of each kind of chemical impurity is specific. Among other things, it depends on magnetic interactions and the differences between host and impurity in ionic mass, ionic volume, and valence electrons. A great deal of work has been done on the specific effects of impurities in electrical resistivity, but little has been done in thermal conductivity. Sometimes even a chemical analysis is not of great help; a given impurity is much more effective as a scatterer if it is in solid solution rather than segregated at grain boundaries or in inclusions. This segregation effect is very pronounced in commercial coppers [44]. Similar interpretive difficulties arise for physical defects.

The variations of thermal conductivity caused by relatively minor chemical impurities or physical imperfections are in sharp contrast to the relative insensitivity to defects observed in thermal expansions or specific heats. Successful prediction of thermal conductivity, within about 10 to 20 percent, is dependent on a skillful analysis of the probable scattering mechanisms and the availability of experimental results on a very similar metal or alloy. As will be shown later, low-temperature electrical resistivity data are also very valuable for predicting thermal conductivity. Much of the pioneering experimental work on the separation of thermal conductivity components for pure metals was done at the Clarendon Laboratory, Oxford, by Rosenberg [33] and others.

A comparison of figures 24a and 46, for example, clearly shows the effects of adding more impurities to a given metal, thereby increasing W_O. A detailed analysis would show that the electron-phonon term, W_L, did not change, that is, it is really intrinsic to aluminum. At low temperatures, the curves are parallel, with the higher impurity alloy lying lower. At higher temperatures, the curves approach each other, the differences decreasing approximately at $1/T$. The detailed methods of analysis and techniques for separation of electronic components of thermal resistivity have been outlined in papers by Powell et al. [45], and by Williams and

Fulkerson [46]. Similar effects of additional impurities can be seen in the curves for copper, iron, and several other alloy systems.

In many low-conductivity alloys, the lattice thermal conductivity, K_g, may be deduced, and the separate scattering components for it may be resolved. For most *alloys*, there are three main processes that effectively limit the lattice conductivity. The first process is scattering of the lattice waves by conduction electrons, as represented by the phonon-electron resistivity, W_E. This is the converse of electrons being scattered by phonons. The second process is scattering by dislocations, the phonon-dislocation resistivity, W_D. The third is scattering by point imperfections, the phonon-point imperfection resistivity, W_P. The first two processes will limit the lattice conductivity at lower temperatures; the third will limit it at higher temperatures. Phonon-electron interactions are coded under Q; phonon-imperfection interaction, under P. For electrical insulators there are additional phonon-phonon scattering processes (seldom observable in electrical conductors) that limit the lattice conductivity at higher temperatures. Those interactions are coded under O.

The phonon-electron and phonon-dislocation resistivities have the same temperature dependence. Therefore, for one alloy specimen, the two scattering mechanisms may not be unambiguously separated. For annealed specimens, the two resistivities will be of about the same magnitude; for unannealed specimens, the dislocation resistivity will greatly outweigh the phonon-electron resistivity. Below about 40 K, the lattice conductivity can be represented by: $1/K_g \equiv W_g = W_E + W_D + W_P = (E + D)T^{-2} + PT$. Because of the T^{-2} dependences of the phonon-electron and phonon-dislocation resistivities, they are dominant at low temperatures and negligible at high temperatures. The maximum in lattice conductivity usually will occur between 50 and 100 K for most alloys. Above those temperatures, however, the lattice conduction is more difficult to separate experimentally from the electronic conduction because the latter has a much greater magnitude [46].

Again the shapes of the curves for aluminum alloys in figure 46 are typical: electronic conductivity is dominant, but lattice conductivity is observable. Again the effects of additional impurities are clear. The detailed methods of analysis and techniques for separation of electronic and lattice conductivity components and further separation of the various lattice resistivity terms have been outlined [45,46]. For aluminum alloys, the lattice conduction may be about 10 percent of the total; for some nickel or iron alloys, it may be much higher, even predominant.

If there is no direct information on the thermal conductivity of a metal, then data on the electrical resistivity may be very helpful. The electrical resistivity may be related to the electronic thermal resistivity by means of the Wiedemann-Franz-Lorenz law:
$\rho = L_0 W_e T$, where L_0 is the Lorenz ratio, assumed to be a fundamental constant given by the Sommerfeld value: $L_0 = \frac{\pi^2}{3}\left(\frac{k}{e}\right)^2 = 2.44 \times 10^{-8}$ [watt-ohm/(deg K)^2], where k is the Boltzmann constant and e is the electronic charge.

A discussion of the separation of components and scattering mechanisms for electrical conductivity follows almost exactly that given above on the electronic thermal conductivity. The total electrical resistivity, ρ, is assumed to be the approximate sum of two separate resistivities, the intrinsic or electron-phonon resistivity, ρ_L, and the residual or electron-imperfection resistivity, ρ_0. In other words, Matthiessen's rule for electrical resistivity, $\rho = \rho_L + \rho_0$, is assumed to be approximately correct.

The expressions for the temperature dependences of the electrical intrinsic and residual terms have been found to be given approximately by: $\rho_L = \alpha' T^n$ (n $\approx$ 4 to 5, $T < 40$ K); $\rho_L = \alpha' T$ (T near 300 K); $\rho_0 = \beta$ (constant). A graph of the separation of electrical resistivity components for a general metal is very similar to that for thermal conductivity in the same metal. Theoretical reviews and expressions for the coefficients α and β have been given by MacDonald [47] and Gerritsen [48], as well as by Ziman [41] and Rosenberg [40].

Lorenz ratios may be calculated for some of the aluminums and aluminum alloys given in figures 24a and 46. The numbers calculated, and shown in figure 2.3.3, express the ratios of the electrical resistivities to the total thermal resistivities divided by T. The extrapolated values, which approach L_0, should represent ratios of electronic terms only because the lattice contribution to the total thermal conductivity is greatly reduced at the lowest temperatures.

It is seen that the Lorenz ratios for the high-conductivity aluminum specimens extrapolate to approximately the Sommerfeld value at 0 K but fall considerably below it at higher temperatures. The behavior of the lower-conductivity aluminum alloys is different: the values between about 10 and 60 K are higher, but above 60 K the values are again lower. For very low conductivity alloys, the ratios approach the Sommerfeld value at low and high temperatures but are much higher at intermediate temperatures. The regions where the ratios are above the Sommerfeld value indicate temperature ranges where lattice conductivity is important.

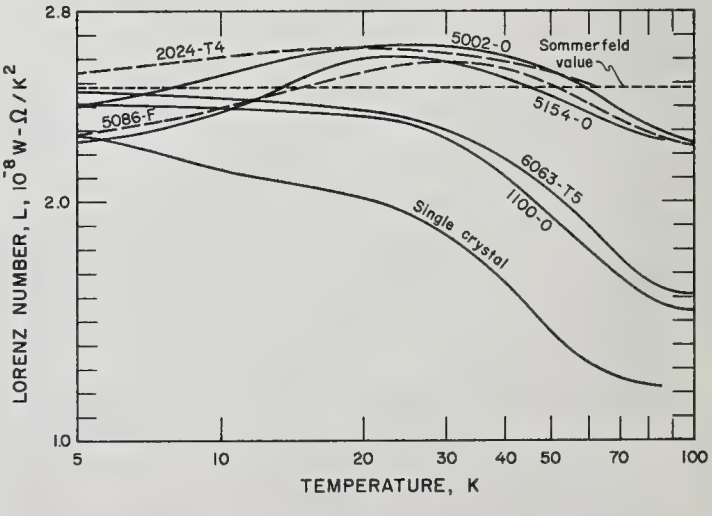


Figure 2.3.3. *Lorenz ratio of some aluminums.*

The Lorenz ratio should be constant if the conduction electrons are scattered elastically and lattice conduction is negligible. That condition is approximately true at high temperatures, where there is a large amount of thermal vibration giving rise to large electron-phonon scattering, and at low temperatures, where the residual term is predominant in the electrical resistivity. At intermediate temperatures, the condition of elastic scattering no longer holds, and Lorenz ratios decrease considerably from the Sommerfeld value, if the lattice thermal conductivity is negligible. Any significant amount of lattice thermal conductivity will raise the Lorenz ratio about the value it would have had if only the electronic term in the thermal conductivity were considered. Whenever authors have calculated the Lorenz ratio, the code S–5 is noted; if only electrical resistivity is given, then S–1 is given and the Lorenz ratio may be calculated if desired.

Very little research has been reported on the Lorenz ratio of commercial alloys. Whenever electrical resistivities for a special material and Lorenz ratios for the general class of materials are available, however, reasonable predictions for thermal conductivity can be obtained.

Nonmetallic solids do not have electronic conduction of course, but in them phonon conduction may become relatively large. They will not have phonon-electron interactions (Q), but will have phonon-imperfection (P) and phonon-phonon (O) interactions. Theories of lattice conduction in insulators are inherently more difficult than electronic theories in metals. Generally the nonmetallic materials have to be more pure than metals to exhibit relatively simple ideal behavior. However, this does occur in a few solids, as in the ionic alkali halides and in valence crystals such as diamond. Ziman [41] has given one of the best discussions of lattice conduction and phonon-phonon interactions.

The many detailed topics in each of the various coded physical phenomena are not discussed extensively. However, a few comments on codes L, M, N, O, P, Q, R, and S are given below.

TABLE 2.3.1. *Code for physical phenomena*

Electronic Thermal Conduction Mechanisms

L. Electron—phonon interactions

1. Temperature dependence—absolute magnitude
2. theories by Wilson, Makinson, Sondheimer, Klemens, and Ziman—coefficients and exponents using characteristics temperatures or phenomenological values
3. phonon polarization—transverse and longitudinal and anharmonic interaction
4. anisotropic scattering
5. Umklapp scattering
6. inelastic scattering
7. diffusion scattering
8. ionic screening
9. Fermi surface geometry

M. Electron—imperfection interactions

1. undifferentiated
2. point imperfection including chemical
3. dislocation, stacking faults
4. grain boundaries
5. external boundaries
6. magnetic impurities, random

N. Electron—miscellaneous scattering interactions

1. separation of components (nonadditive)
2. magnetic field dependence
3. superconductivity
4. anisotropy
5. intra- and interband scattering (band structure), density of states effects
6. magnetic ordering, spin waves, magnons
7. mean-free-path (size effect)
8. nonlinearity in WT versus T^3 curves
9. electron—electron
10. irradiation effects
11. electric field dependence

Lattice Thermal Conduction Mechanisms

O. Phonon—phonon interactions

1. undifferentiated
2. normal, theories by Peierls, Ziman, Klemens, Leibfried and Schlömann, and Callaway
3. Umklapp—anharmonic
4. pressure dependence
5. mean-free-path (size effect), or relaxation time
6. anisotropy
7. separation of components (nonadditive)
8. Poiseuille flow
9. transverse—longitudinal, acoustic, and optical interaction

P. Phonon—imperfection interactions

1. undifferentiated
2. point
3. dislocation
4. grain boundaries
5. external boundaries
6. stacking faults
7. energy transitions—internal degrees of freedom, molecular vibrations
8. isotope, mass difference
9. strain field
10. magnetic impurities
11. vacancies
12. composition variation
13. irradiation effects
14. color centers
15. clusters or colloids

Q. Phonon—electron interactions

1. general
2. transverse—longitudinal interaction
3. alloying variation
4. Fermi surface effects and band interaction
5. spin waves

TABLE 2.3.1 *Code for physical phenomena*—Continued

Miscellaneous Phenomena

R. Miscellaneous carriers

1. ambipolar diffusion
2. magnons
3. photons
4. excitons
5. polarons

S. Other experimental properties

1. electrical resistance
2. thermoelectric
3. specific heat
4. magnetic moment
5. Lorenz ratio
6. thermal expansion

Electronic Thermal Conduction Mechanisms

L. Electron-Phonon Interactions

Electron-phonon interactions are dominant in pure metals for temperatures above the temperature where the maximum in thermal conductivity occurs. They are also significant, but not dominant, in alloys. The absolute magnitude and temperature dependence of this interaction, coded L–1, are the most commonly explored phenomena in thermal conductivity experiments. Authors frequently compared their results to the predictions of theories by Wilson, Makinson, Sondheimer, Klemens, or Ziman (coded L–2), theories reviewed and summarized by Ziman [41] and Klemens [39]. Although those theoretical analyses were rather elegant mathematically, they were usually based on oversimplified physical assumptions—such simplifications as only electron-longitudinal phonon interactions, spherical Fermi surfaces, isotropic scattering angles, etc. Klemens [39] and Ziman [41] have led in the attempts to provide more rigorous, and therefore more complex, foundations for the theories. Their studies, and also those of other recent theoreticians, have considered the effects coded as L–3 through L–9: phonon polarization; anisotropic, Umklapp, inelastic, or diffusion scattering; ionic screening; and Fermi surface geometry. Generally speaking, it has not been possible to get good quantitative, unambiguous agreement between theoretical predictions and the magnitudes of the corresponding experimental values.

M. Electron-Imperfection Interactions

These interactions are dominant in alloys and in metals below their conductivity maximum. Most authors have not characterized their specimens well enough physically to determine which imperfections are most important. Therefore the undifferentiated coding M–1 is most common. However, some of the more careful experimentalists made detailed characterizations and analyses and were able to isolate the effects of different types of imperfections, those coded as M–2 through M–6. Point imperfections, including chemical impurities, (M–2), are the easiest to determine accurately and were naturally the most commonly analyzed. Three other imperfections are also relatively easy to distinguish: dislocations and stacking faults (M–3), grain boundaries (M–4), and external boundaries (M–5). The last one is seldom important in metals or alloys. Random magnetic impurities (M–6) can become very important in some dilute alloys and pure metals, e.g., a few parts per million of iron in copper or gold radically change electronic properties near helium temperatures.

N. Electron-Miscellaneous Scattering Interactions

In addition to the relatively simple and general groups of scatterers listed in code M, there are several other scattering mechanisms and phenomena that are important in special metals and alloys. For example, nonadditivity (N–1) can become important in relatively pure metals. Magnetoresistance (N–2) can be important both for design data and for elucidating some electron interaction effects. A large amount of research has been carried out on superconductors (N–3) below their transition temperature. Although a magnetic field was often used to destroy superconductivity so that the normal state properties could be determined, such experiments were not coded with N–2 unless magnetic field effects were studied in the normal state. In the graphs the superconducting state curve is marked with an (s) and is dashed. Because metals in their superconducting state have fewer electrons available for thermal energy transitions, pure metals have a lower thermal conductivity when they are in the superconducting state. Many authors have utilized single crystals in order to have perfect specimens. Crystals without cubic symmetry can then demonstrate their anisotropic electronic properties (N–4). In some alloys, semimetals, and semiconductors intra- and interband scattering (N–5) can become important. In ferro- and ferrimagnetic metals there can be magnetic ordering, and magnetic spin waves or magnons (N–6), that act as scattering agents for conduction electrons. Other effects, seldom observed in conduction electron interactions, such as size effects, nonlinearity in WT versus T^3 plots, electron-electron scattering, irradiation damage, and electric field dependence are coded in N–7 through N–11.

Lattice Thermal Conduction Mechanisms

In insulators that are chemically pure and physically perfect, lattice conduction can give high values for thermal conductivity. Lattice conduction is also dominant in semiconductors and can be important in some alloys and possibly in some transition metals. Quantized lattice waves, phonons, can be scattered by other phonons (Code O), by physical or chemical imperfections (P), or by electrons (Q), in materials that have

conduction electrons. The most progress in correlating experimental results and theoretical predictions has been achieved for the relatively ideal materials such as solid helium, ionic alkali halides, and valence crystalline diamond and quartz.

O. Phonon-Phonon Interactions

Since phonon-phonon interactions are difficult to calculate theoretically and hard to unambiguously analyze experimentally, most research papers merely report undifferentiated temperature-dependent phonon intractions. When detailed comparisons have been made between experimental research and theoretical predictions, the relevant theories were usually those of Peierls [49], Ziman [41], Klemens [39], Leibfried and Schlömann [50,51], or Callaway [52], or their coworkers (O–2).

Most classical theories of phonon interactions have presumed local conservation of momentum; when this restriction is eased to include in the process nonconservative interactions, the word "Umklapp" (O–3) is used. Several other, less often observed effects are also included in this coding category: pressure dependence (O–4), for soft crystals like helium; phonon relaxation time studies (O–5), for many different crystals; anisotropy (O–6), for noncubic single crystals; nonadditive separation of components (O–7), for some crystals near their conductivity maximum; Poiseuille flow (O–8), for relatively long, thin crystals at very low temperatures where the mean-free-path of the phonons is comparable to or larger than the width of the specimens; and various phonon polarizations (O–9), besides longitudinal, including the various branches in the phonon dispersion curves.

P. Phonon-Imperfection Interactions

In most electrically insulating crystals, imperfections are dense enough to be the main limitation to phonon heat conduction. Again, physical characterization of the type and extent of the imperfections is necessary for correlation with theoretical predictions. Since this was usually not done, most reports commenting on phonon-imperfection interactions are coded as undifferentiated (P–1). There are, however, many comprehensive papers that have made careful characterizations and correlations for point imperfections (P–2), dislocations (P–3), grain boundaries (P–4), and stacking faults (P–6), in ionic, valence, and molecular crystals, and in semiconductors and alloys. Grain boundary scattering is especially important in solids with very small crystallites, e.g., graphite. External boundary scattering (P–5) is dominant at low temperatures in nearly ideal crystals like diamond and solid helium. Isotopic scattering (P–8) is also important in nearly perfect crystals, but is more pronounced at intermediate, rather than very low, temperatures. Some molecular crystals have energy transitions (P–7) low enough in energy to be significant in thermal transport.

Codes P–9 through P–15 are used to cover a miscellaneous collection of other phonon-imperfection mechanisms that are occasionally observed.

Q. Phonon-Electron Interactions

Commercial alloys, and even some dilute binary alloys, have a sufficiently low electronic thermal conductivity that lattice conductivity can be observed. In these materials the main phonon scatterer is often the conduction electrons. Uusually the interaction is not analyzed in detail (Q–1), but some authors have given more thorough analyses, in particular attempting to resolve the transverse and longitudinal phonon interactions (Q–2). Studies of the alloying variation (Q–3) of phonon-electron interactions are also available, especially for dilute alloys. Two other effects noticed are band-structure of Fermi surface modifications (Q–4) and magnetic alterations (Q–5) of the basic interaction.

Miscellaneous Phenomena

R. Miscellaneous Carriers

Any mobile excited state of lattice vibrations or electrons or groups of them may act as heat carriers. There are several mechanisms for carrying heat besides simple phonons and isolated electrons or holes. The five that may occur in a significant way at low temperatures are ambipolar diffusion, magnons, photons, excitons, and polarons. Each of these will be discussed in more detail below. In addition, the rotational molecular specific heat in such molecular crystals as CH_4 may be a carrier of thermal energy near the crystals' order-disorder transition temperature, e.g., near 20 K for CH_4. However, the phenomenon is not widely observed and is not further described. We only coded these phenomena if the authors themselves recognized the presence of nonsimple transport mechanisms.

1. *Ambipolar diffusion*

Busch and Schneider [53] observed in the semiconductor InSb a thermal conductivity that was much higher than that which could be explained by simple addition of lattice or phonon and electronic conduction mechanisms. An explanation of the effect, called ambipolar diffusion, was given by Fröhlich and Kittel [54] in an accompanying note and also by P. J. Price [55]. A more thorough discussion has been given by Drabble and Goldsmid [56] in their book on thermal conduction in semiconductors. Ambipolar diffusion refers to transport of heat by means of the ionization energy for an electron-hole pair. An electron-hole pair can be formed at the hot end of the thermal conductivity specimen, absorbing the band gap energy, E_g from the heat source. The hole and electron then diffuse *separately* to the cold end of the specimen, recombine, and liberate the energy E_g. If the number of electrons and holes is about equal and the semiconductor is intrinsic, there can be a substantial contribution to thermal transport without any net electric charge flow. However, if either carrier, electron or hole, is dominant or their mobilities are quite different, there wil not be any significant heat transport by ambipolar diffusion. This mechanism is very similar to exciton transport in semiconductors, except that in exciton transport in semi-

conductors the electron-hole pair are bound in a stable arrangement and drift across the specimen together. Ambipolar diffusion occurs in many different intrinsic semiconductors but is effective mainly at higher temperatures, near room temperature or above.

2. *Magnons*

Magnetic spin waves may occur in ferro-, ferri-, and antiferro-magnetic materials. Magnons are quantized spin waves in the same manner that phonons are quantized lattice waves. Kittel [57] has given a good introduction to spin waves and magnons. Rezanov and Cherepanov [58] calculated the contribution of magnons to thermal conductivity for ferromagnetic ma- has been difficult to unambiguously obtain. Sato [59] terials, but experimental verification of their presence has been difficult to unambiguously obtain. Sato [59] also calculated the magnon contribution for ferromagnetic insulators. In 1961 experiments by Douthett and Friedberg [60] on ferrimagnetic crystals and by Slack [9] on antiferromagnetic crystals seemed to indicate a measurable magnon term. More definite verification of magnon conduction has recently been observed below 1 K in complex hydrated ferromagnetic copper ammonium bromides by Haasbroek and Gieske [61]. However, in general the phenomena is not widely or unambiguously observed at low temperatures.

3. *Photons*

Quantized electromagnetic waves, photons, were the first cooperative wave phenomena to be given a special name and assigned a pseudo-particle behavior. If a solid is partially transparent to photons of the appropriate wavelengths, then those photons can transmit energy through the solid. Significant thermal transport by photons occurs only in a few valence crystals and semiconductors and, in them, it is only important at moderately high temperatures. Its temperature dependence is about cubic; near room temperature photon conductivity can represent 10 to 25 percent of the total conductivity in a few materials. In 1961 Busch, Frölich, Hulliger, and Steigmeier [62] and Petrusevich, Sergeeva, and Smirnov [63] observed significant photon conductivity in $SnSe_2$ and In_2Te_3, respectively. Both experiments agreed well with the earlier theoretical predictions of Genzel [64].

4. *Excitons*

An electron-hole pair with a significant lifetime may be formed in semiconductors, ionic crystals, or molecular crystals. The pair have an excitation energy; they may move through the crystal transporting this energy but carrying no net effective electric charge. If the pair move separately and independently, this leads to an ambipolar diffusion conductivity contribution as described in section R–1. However, since the electron and hole have an attractive Coulombic interaction, a stable-bound state of the two has a lower energy. This bound state. mobile, neutral electron-hole pair is called an exciton. As described by Kittel [57], there are two theoretical aproximation limits, the tightly bound Frenkel condition, and the weakly bound Mott-Wannier condition. The latter are important in semiconductor conductivity; the former, in alkali halides.

There has been very little clear experimental evidence of thermal conductance by excitons within the temperature range covered in this review. Mrs. Devyatkova [65] believed that she observed the phenomenon in PbTe; she obtained results that were at least consistent with the possibility of exciton conductivity calculated by Pikus [66]. However, in her later research that includes PbTe she does not mention the phenomenon again.

5. *Polarons*

An electron moving through an ionic crystal polarizes the lattice around it. When the electron moves, the polarization will move with it. If the energy exceeds a certain amount, a phonon may be produced, and the electron will be strongly scattered or accelerated. Even when the electron is moving more slowly there is the theoretical possibility of the excitation and reabsorption of virtual phonons, which change the effective self-energy of the particle. This extra energy is itself a function of the velocity, and thus apears as a correction to the "mass" of the carrier. The polaron, consisting of a point charge surrounded by a cloud of 'virtual phonons', is an observable entity in some ionic crystals. Because of the close interaction with the heavy ions, the electron acts as if its mass were considerably increased. The polaron effect will be strongest in strongly ionized crystals, weakest in those that are largely covalent.

Again there has been no unambiguous experimental verification of the effects of polarons on thermal conduction at room temperature or below. Bogomolov et al. [67] calculated that the effect was too small to be observed, even in their TiO_2 specimens.

S. Other Properties

In experimental studies on the thermal conductivity of solids, other properties are sometimes determined for the same specimens. Correlations between these other properties and thermal conductivity often exist. It is sometimes possible to estimate accurate values of thermal conductivity from values of other properties, thus eliminating a considerable difficulty or expense of the actual experimental measurement. Data on other properties are also valuable in interpreting various components of thermal conductivity.

1. *Electrical resistivity*

The electrical resistivity may be related to the electronic component of thermal resistivity by means of the Wiedemann-Franz-Lorenz law: $\rho = L W_e T$, where L is the Lorenz ratio (discussed in sec. S-5). The total electrical resistivity ρ may be separated into components much like that of the electronic thermal resistivity, with the sum of two separate resistivities, ρ_L, the intrinsic or electron-phonon resistivity, and ρ_0, the residual or electron-imperfection resistivity. Thus,

$\rho = \rho_L + \rho_0$, or Matthiessen's rule, is assumed to be approximately correct.

As mentioned in section 2.1, the electrical residual resistance ratio (denoted by *RRR* in the Sample Source column of the tables) is a good indicator of the purity of a sample. Since ρ_L vanishes *as* $T \rightarrow 0$ K, then the greater the value of *RRR* (where $RRR \equiv \rho(T \rightarrow 0\ \mathrm{C}) / \rho(T \rightarrow 0\ \mathrm{K})$), the greater the purity of the sample. One of the highest purity samples in this compilation was the Al-1 measured by Seeberg and Olsen [68], with *RRR* = 24,000.

Thorough discussions of the electrical resistivity of solids at low temperatures appear in Rosenberg [40] and Meaden [69].

2. *Thermoelectric properties*

There are a number of thermoelectric effects in metals, which involve direct reversible interchange between thermal and electric energy, and certain other types of interactions between temperature gradients and potential gradients. In any metal in which there exists a temperature gradient it is expected to find a variation of the electron energy distribution function with temperature. At normal or low temperatures a small fraction of the electrons have energies in a narrow region at the top of the Fermi-Dirac distribution. As the temperature is raised, this narrow region expands, resulting in slightly more electrons having higher energies than before. Thus, electrons will travel to the lower temperature and under a thermal gradient carry excess thermal energy. To preserve the requirement of no net current flow (since it is not a closed circuit electrically) a return flow of electrons carrying their normal negative charge, but no excess thermal energy, takes place. This return flow is produced by an electrical driving force, a potential difference ΔE divided by the temperature difference between the two ends. This effect is the basis for thermocouples.

3. *Specific heat*

The specific heat at constant volume of a metal is defined as $C_v \equiv \left(\frac{\partial U}{\partial T}\right)_v$, where U is the total internal energy of the metal or alloy system and T is the absolute temperature. The theoretical problem is to determine the variation of the energy with temperature. There are two main types of energy variation. In the first type, the energy and consequently the specific heat are slowly varying functions of temperatures. In a metal, the internal energies of the ionic lattice and of the free or conduction electrons are typical examples. In the second type, a particular type of internal energy changes significantly only over a restricted temperature range. The energies of transformation for phase changes and magnetic ordering are examples of the latter type. The specific heat contribution for the transformation in these processes is observable only over the same restricted temperature range as the energy change. The restricted temperature range or anomalous specific heats are of tremendous importance for physics and chemistry research, but usually are not of great significance in commercial metals. Rosenberg [40] and Gopal [70] give a low-temperature review of the specific heat.

4. *Magnetic moment*

When a sample is placed in a magnetic field, an effective magnetic dipole moment is induced. Generally there are three main types of behavior observed with the magnetic dipole moment: diamagnetism, paramagnetism, and ferromagnetism. Paramagnetism, when the induced magnetic dipole moment is in the same direction as the field and also proportional to it, is the one type of behavior which has the largest low-temperature interest because, in a paramagnetic, the dipole moment increases very much as the temperature is reduced. The other types do not change at low temperatures.

5. *Lorenz ratio*

The Lorenz ratio, L, found in the Wiedemann-Franz-Lorenz law, is assumed to be a fundamental constant given by the Sommerfeld value: $L_0 = (\pi^2 k^2)/(3e^2) = 2.44 \times 10^{-8}$ watt-ohm/(deg K)^2. This simple relationship between the electrical and thermal conductivities is obtained because the mean-free-path term was canceled on assumption that its value for thermal and electrical conduction is the same. This is a legitimate assumption only when the scattering is elastic, by impurities at very low temperatures, or by phonons at very high temperatures.

Lorenz ratios for high-conductivity speciments extrapolate to approximately the Sommerfeld value at 0 K but fall considerably below it at intermediate temperatures. Values for low-conductivity alloys are quite different: the values at low temperatures are much higher than L_0 and generally decrease toward L_0 at higher temperatures. The Lorenz ratios for intermediate conductivity alloys show a more complex behavior: at low temperatures the ratios are higher than L_0, at intermediate temperatures the ratios fall below L_0, and at high temperatures they approach L_0. The regions where the ratios are above the Sommerfeld value indicate temperature ranges where lattice conductivity is important.

6. *Thermal expansion*

A small yet important consideration in many cryogenic experiments is the thermal expansion. It is usual to select the same material for the different parts of the apparatus because it lessens the risk of strains arising from differential expansion or contraction. In designing equipment, both thermal expansion and thermal conductivity data are often necessary. Many of the thermal conductivity research reports aimed toward design data therefore include thermal expansion information.

The authors thank J. G. Hust and D. L. McElroy for their many helpful suggestions. The layout and typing

of the tables, text, and index by M. Birchfield, C. Dallman, and K. Bowie is greatly appreciated, as is the assistance of R. Weekly on the drawing of some of the figures. The early phases of this work were funded by the NASA-Office of Advanced Research and Technology, Washington, D. C.

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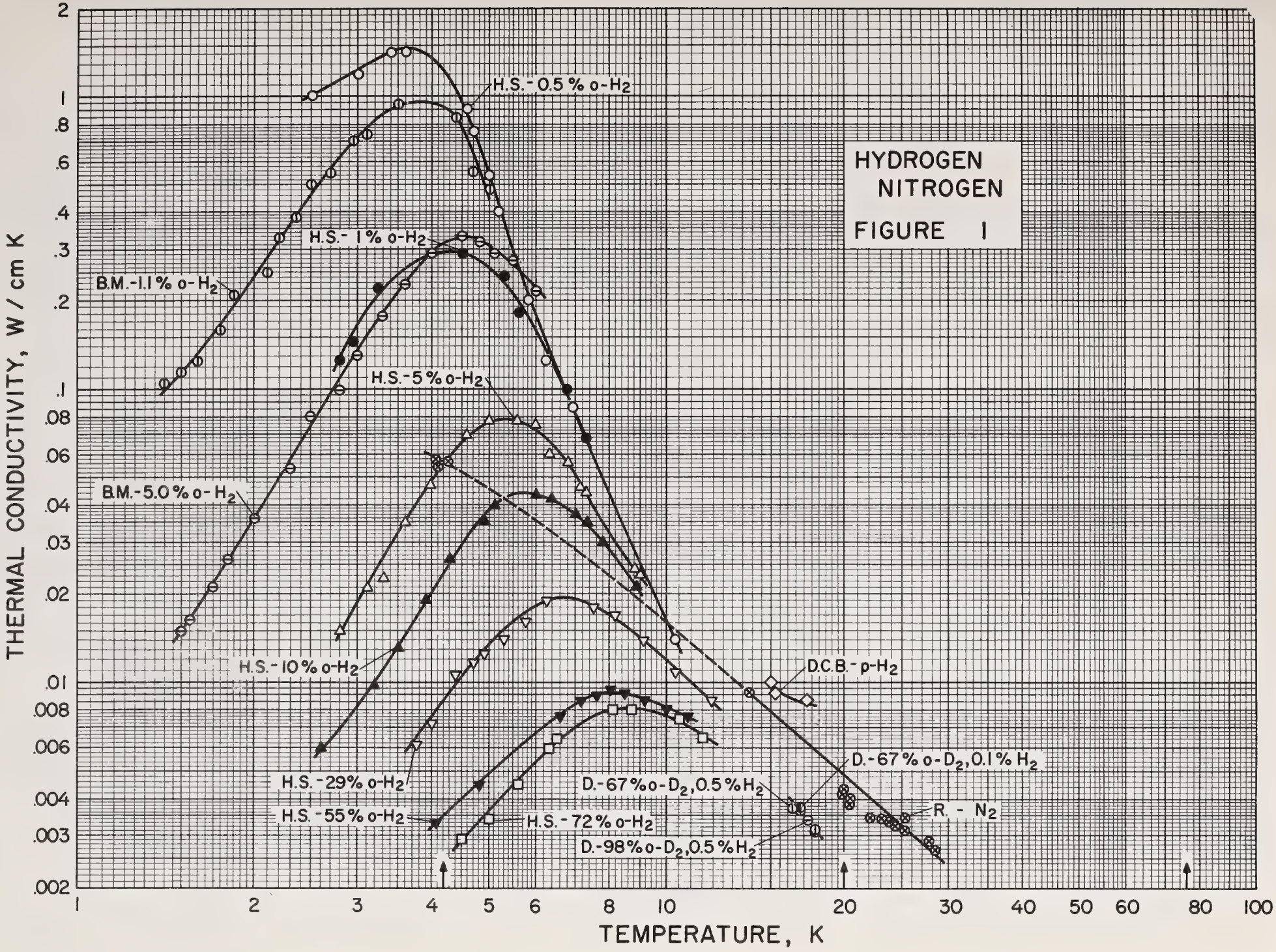
[70] Gopal, E. S. R., Specific Heats at Low Temperatures (Plenum Press, New York, 1966).

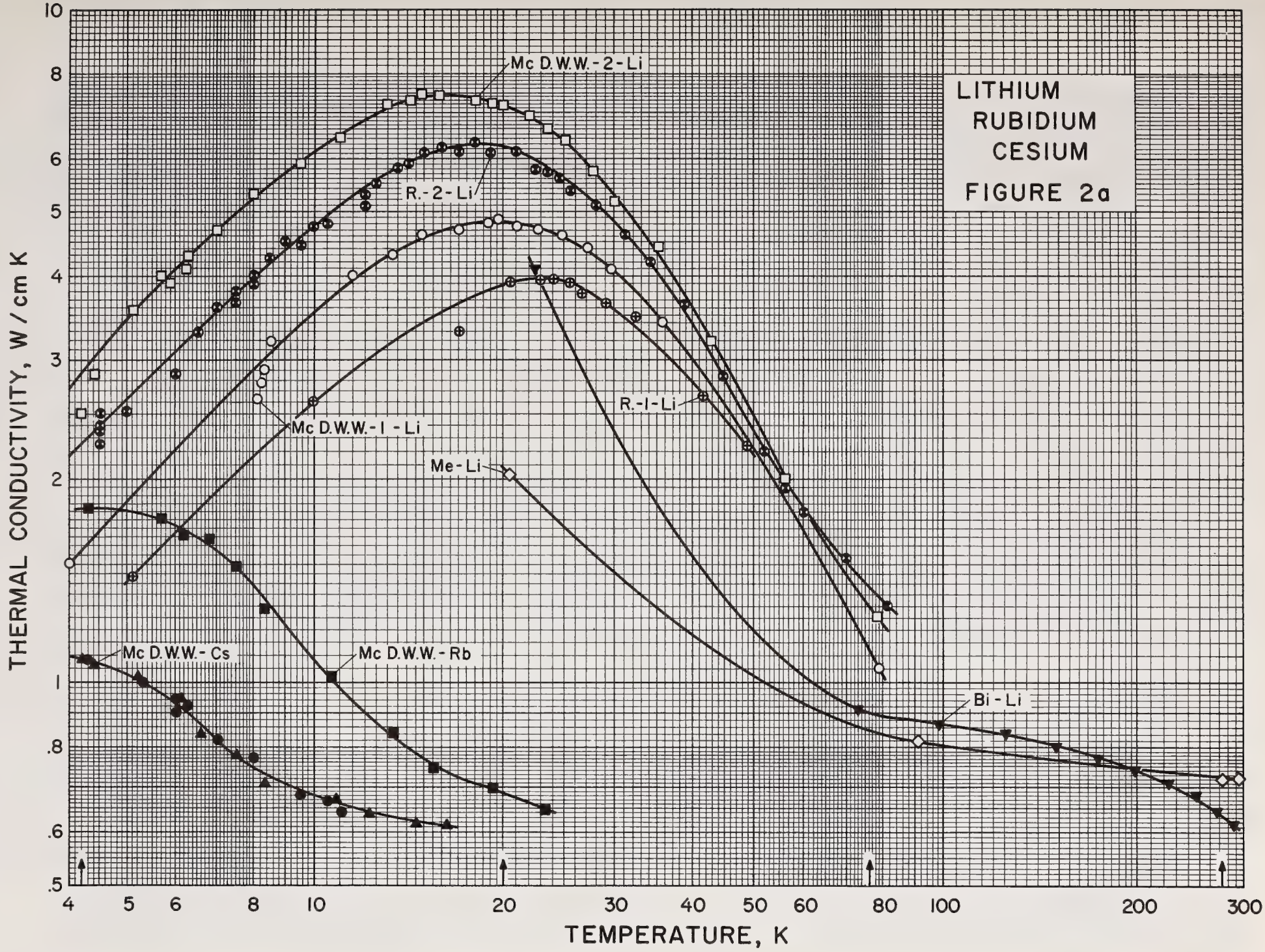
3. TABLES AND FIGURES

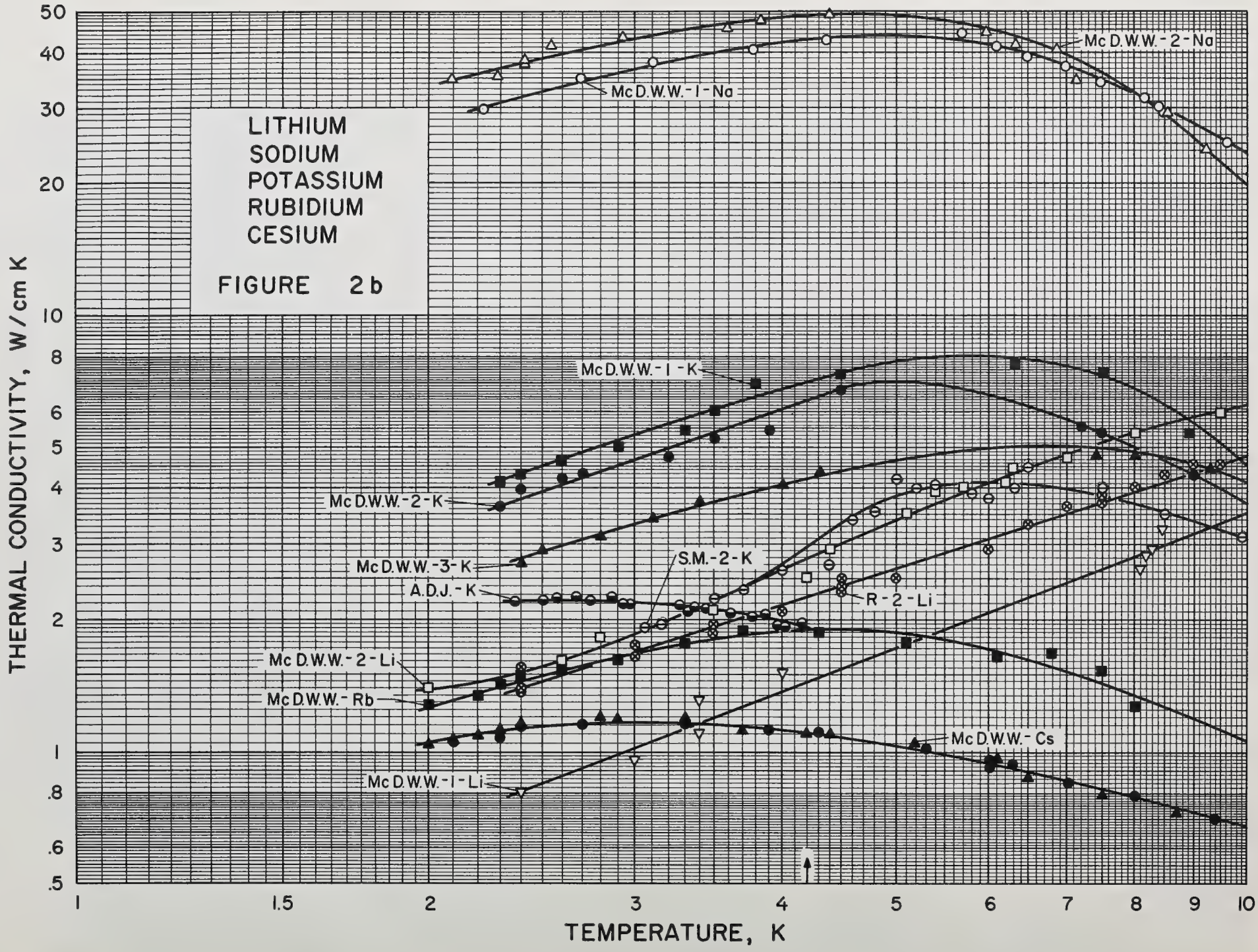
3.1. ELEMENTS


HYDROGEN
NITROGEN
FIGURE 1
H.S. - 0.5 % o-H2
H.S. - 1 % o-H2
B.M. - 1.1 % o-H2
H.S. - 5 % o-H2
B.M. - 5.0 % o-H2
H.S. - 10 % o-H2
D.C.B. - p-H2
H.S. - 29% o-H2
D. - 67 % o-D2, 0.1 % H2
D. - 67 % o-D2, 0.5 % H2
R. - N2
H.S. - 55 % o-H2
H.S. - 72 % o-H2
D. - 98 % o-D2, 0.5 % H2
THERMAL CONDUCTIVITY, W / cm K
TEMPERATURE, K
2
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
.01
.008
.006
.004
.003
.002
1
2
3
4
5
6
8
10
20
30
40
50
60
80
100

HYDROGEN
(See FIGURE 1)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
H.S.-0.5%, 1%, 5%, 10%, 29%, 55%, 72% o-H_2	. . . . .	5 cm crystals, grown and annealed in place in a glass cylinder; no optically apparent defects. The numbers indicate the percentage of molecules in the ortho state; the remainder are para.	A-1; B-1; C-1; D-3(2); E-4, 5; F-5; G-3; N-7; O-1; P-4, 7.	R.W. Hill and B. Schneidmesser (1958).
D.C.B.-p-H_2	99% p-H_2, 1% o-H_2.	Grown in place in a stainless steel cylinder. Measured at pressures between 88 and 200 atm.	A-1; B-2; C-1; D-3(3); E-5; F-5; G-3; O-1, 4.	R.F. Dwyer, G.A. Cook, and O.E. Berwaldt (1966).
B.M.-0.2%, 1.1%, 5.0% o-H_2	. . . . .	Prepared by placing 5% o-H_2 liquid in contact with chrome alumina catalyst for several hours; after measurement at specific concentration, stored at room temperature several days allowing para-to-ortho conversion; then remeasured. The numbers indicate the percentage of molecules in the ortho state; the remainder are para. Four intermediate ortho-concentrations were also measured, with intermediate results. Condensed at about 20 K in stainless steel tube, cooled to triple point, frozen into single crystals; a few thread-like imperfections.	A-1; B-1; C-1; D-2(1); E-5; F-4; G-2; O-3, 5; P-1, 2, 4, 5.	R.G. Bohn and C.F. Mate (1970).
D.-98% o-D_2, 0.5% H_2; 67% o-D_2, 0.1% H_2; 67% o-D_2, 0.5% H_2	0.5% H_2, 99.5% D_2 of which 98% is ortho phase; 0.1% H_2, 99.9% D_2 of which 67% is ortho phase; 0.5% H_2, 99.5% D_2, of which 67% is ortho phase.	Frozen in place in a plastic tube. 67% o-D_2: 20 K equilibrium; 3 mm diameter grains.	A-3; B-1; C-1; D-1(2); E-5; F-4; G-3; O-3.	D.E. Daney (1971).

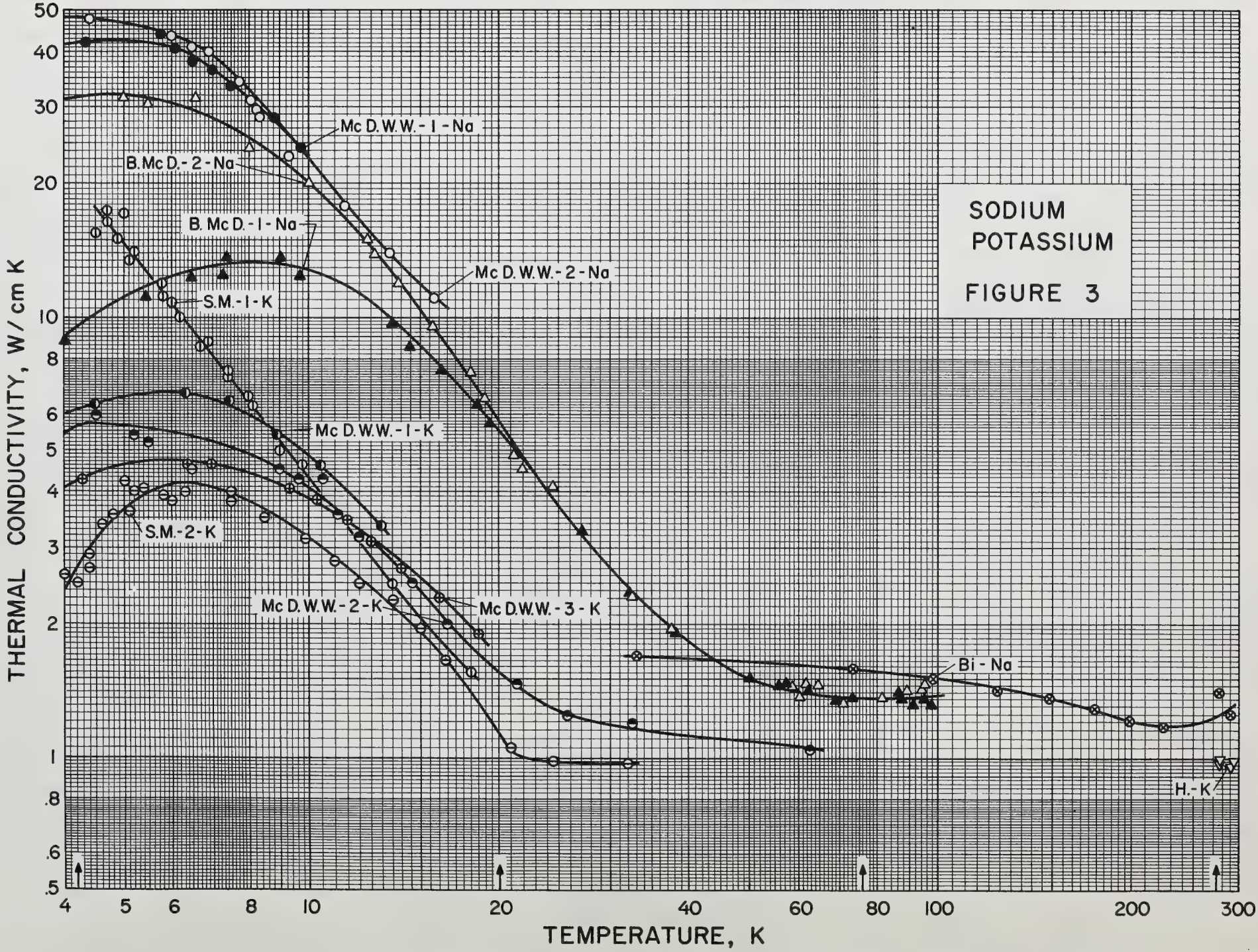

LITHIUM
RUBIDIUM
CESIUM
FIGURE 2a
Mc D.W.W.-2-Li
R.-2-Li
Mc D.W.W.-1-Li
R.-1-Li
Me-Li
Bi-Li
Mc D.W.W.-Cs
Mc D.W.W.-Rb
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
10
8
6
5
4
3
2
1
.8
.6
.5
4
5
6
8
10
20
30
40
50
60
80
100
200
300


LITHIUM
SODIUM
POTASSIUM
RUBIDIUM
CESIUM
FIGURE 2b
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
50
40
30
20
10
8
6
5
4
3
2
1
.8
.6
.5
1
1.5
2
3
4
5
6
7
8
9
10
Mc D.W.W.-2-Na
Mc D.W.W.-1-Na
Mc D.W.W.-1-K
Mc D.W.W.-2-K
Mc D.W.W.-3-K
A.D.J.-K
S.M.-2-K
R-2-Li
Mc D.W.W.-2-Li
Mc D.W.W.-Rb
Mc D.W.W.-Cs
Mc D.W.W.-1-Li

LITHIUM

(See FIGURES 2a and 2b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
Me.-Li	Kahlbaum; "very pure".	Cold worked; handled in CO_2 atmosphere.	A-4; B-1; C-3; D-1(2); E-5; F-5; G-3; L-1; M-1; S-1.	W. Meissner (1920).
Bi.-Li	. . . . .	Extruded and mounted in glass tubes; cycled thermally.	A-5; B-1; C-1; D-1(6); E-8; F-5; G-3; L-1; M-1; S-1, 3,5.	C. C. Bidwell (1926a, b, 1925).
McD. W. W.-1, 2-Li	"High purity". #1: New Metals and Chemicals, Ltd. (London); RRR(22)= 137. #2: A. D. McKay; RRR(22) = 254.	Extruded with hydraulic press into a stainless steel tube with a lubrication film of petroleum jelly on the inside walls of the tube. Graph of intrinsic thermal resistivity.	A-1; B-1; C-1; D-4(2); E-1, 5; F-4; G-2; L-1-9; M-1; S-1, 5.	D. K. C. MacDonald, G. K. White, and S. B. Woods (1956).
R.-1, 2-Li	"High purity". #1: RRR(20) = 100. #2: RRR(20) = 200.	Distilled into a stainless steel capillary. Intrinsic thermal resistivity available from graphs of WT versus T^3.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2, 5; M-1; S-1, 5.	H. M. Rosenberg (1956).


SODIUM
POTASSIUM
FIGURE 3
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
Mc D.W.W.-1-Na
B.Mc D.-2-Na
B. Mc D.-1-Na
Mc D.W.W.-2-Na
S.M.-1-K
Mc D.W.W.-1-K
S.M.-2-K
Mc D.W.W.-2-K
Mc D.W.W.-3-K
Bi-Na
H.-K
50
40
30
20
10
8
6
5
4
3
2
1
.8
.6
.5
4
5
6
8
10
20
40
60
80
100
200
300

SODIUM

(See FIGURES 2b and 3)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	Eimer and Amend; "very pure"; "free from Fe, Ca, Mg, Al, and K" by chemical analysis.	Melted and cast in glass in vacuum. k = 1.34 at 5.7°C; k = 1.33 at 21.0°C.	A-4; B-1; C-3; D-1(3); E-7; F-5; G-3; L-1; M-1; S-1.	J.W. Hornbeck (1913).
Bi.-Na	. . . . .	Extruded and mounted in glass tubes; cycled thermally.	A-5; B-1; C-1; D-1(6); E-8; F-5; G-3; L-1; M-1; S-1, 3, 5.	C.C. Bidwell (1926a, b, 1925).
B.McD.-1, 2-Na	#1: British Thompson-Houston; 0.01 to 0.1% Ca and Al. #2: Philips; trace of Ag.	Melted, cast in vacuum into soft glass.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1; N-7; S-1, 5.	R. Berman and D. K.C. McDonald (1951).
McD.W.W.-1, 2 Na	Phillips; "of exceptional purity". #1: RRR(22) = 2860. #2: RRR(22) = 3500.	Melted in vacuum, run into soft-glass tubes. Graph of intrinsic thermal resistivity.	A-1; B-1; C-1; D-4(2); E-1, 5; F-4; G-2; L-1-9; M-1; S-1, 5.	D.K.C. MacDonald, G.K. White, and S.B. Woods (1956).
. . . . .	Phillips; "of exceptional purity". #1: RRR(22) = 2860. #2: FFF(22) 3500.	Measured the thermal magnetoresistance in transverse magnetic fields up to 1 T between 2 and 18 K.	. . . . .	G. K. White and S. B. Woods (1956 c).

POTASSIUM

(See FIGURES 2b and 3)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
H.-K	Eimer and Amend;"very pure"; free from Fe, Ca, Mg, Aℓ; trace of Na by chemical analysis.	Melted in vacuum and cast in glass.	A-4; B-1; C-3; D-1(3); E-7; F-5; G-3; L-1; M-1; S-1.	J. W. Hornbeck (1913).
McD. W. W.-1, 2, 3-K	Pure Metals Research Committee, specially prepared by ICI; "high purity". #1: RRR(22) = 531. #2: RRR(22) = 513. #3: RRR(22) = 324.	Melted in vacuum, run into soft glass tubes. Graph of intrinsic thermal resistivity.	A-1; B-1; C-1; D-4(2); E-1, 5; F-4; G-2; L-1-9; M-1; S-1, 5.	D. K. C. MacDonald, G. K. White, and S. B. Woods (1956).
A. D. J.-K	J. T. Baker Chemical Co.; "exceptionally pure"; RRR (23) = 2800.	Melted and then cast into a nylon tube.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-2; L-1; M-1; S-1.	M. A. Archibald, J. E. Dunick; and M. H. Jericho (1967).
S. M.-1, 2-K	Mine Safety Appliances Corporation; 99.97% pure. #1: not zone refined. #2: zone refined from the bulk material.	Single crystals using the Bridgeman method. An additional crystal was measured giving the same results as #2. Graphs of intrinsic thermal resistivity and lattice thermal conductivity.	A-1; B-1; C-1; D-3(2); E-3; F-4; G-3; L-1, 2; M-1; P-1; Q-1, 2; S-1.	R. F. Stauder and E. V. Mielczarek (1967).

RUBIDIUM

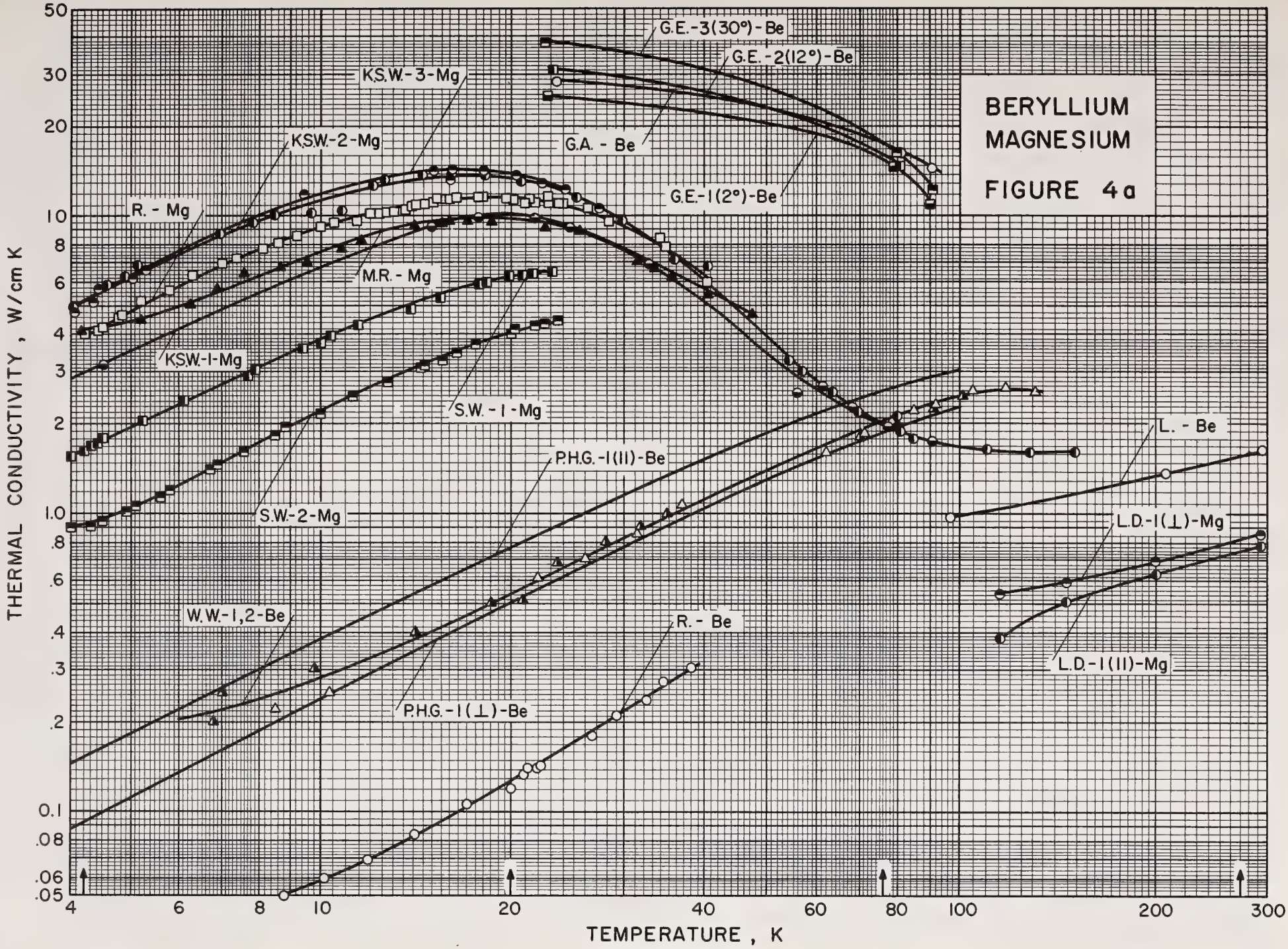
(See FIGURES 2a and 2b)

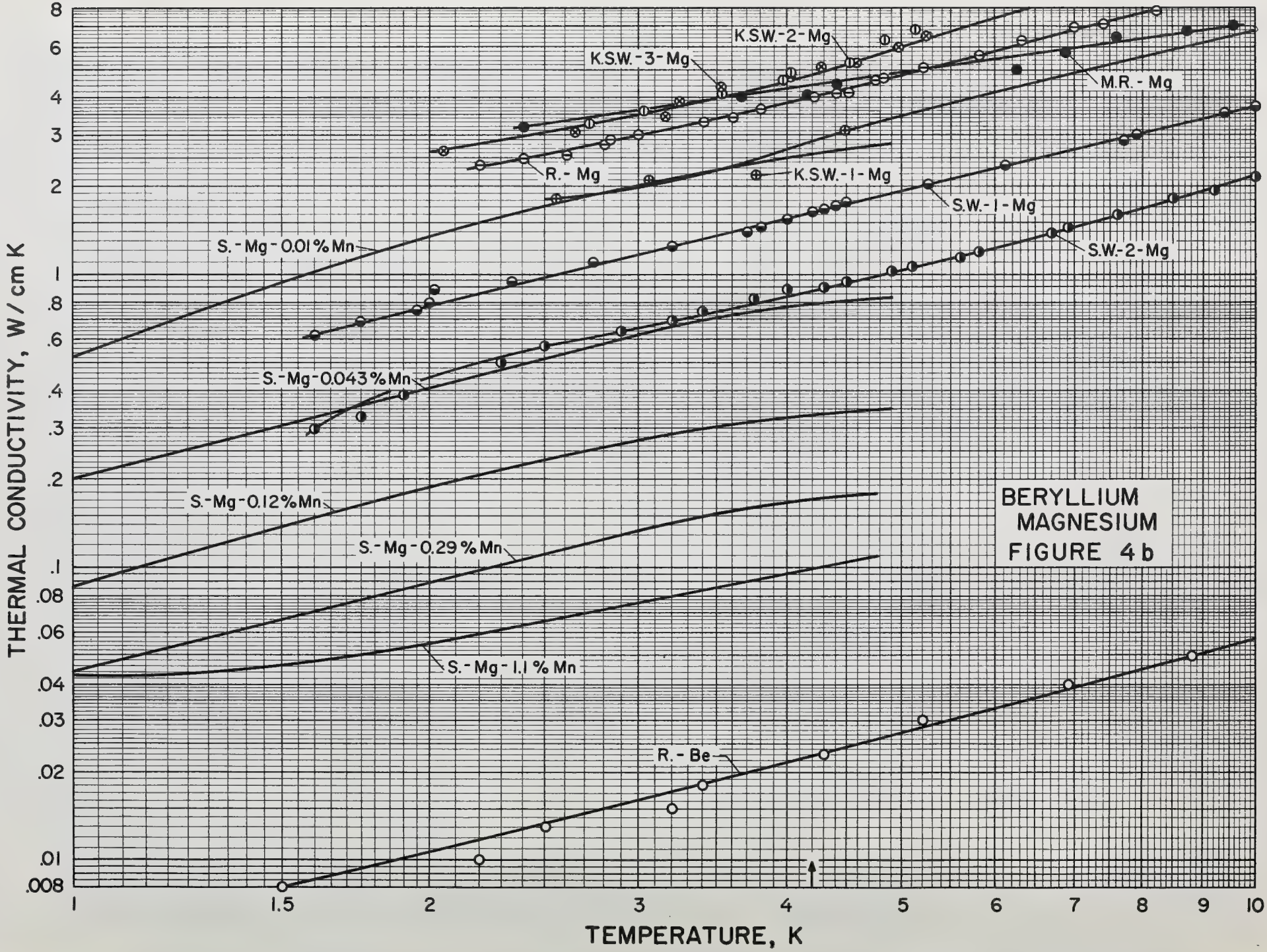
CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
McD. W. W. -Rb	A. D. McKay; "high purity"; RRR(22) = 380.	Melted in vacuum, run into soft-glass tubes. Graph of intrinsic thermal resistivity.	A-1; B-1; C-1; D-4(2); E-1,5; F-4; G-2; L-1-9; M-1, S-1, 5.	D. K. C. MacDonald, G. K. White, and S. B. Woods (1956).

CESIUM

(See FIGURES 2a and 2b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
McD.W.W.-Cs	A.D. McKay; "high purity"; RRR(22) = 497.	Melted in vacuum, run into soft-glass tubes. Two separate runs. Graph of intrinsic thermal resistivity.	A-1; B-1; C-1; D-4(2); E-1,5; F-4; G-2; L-1-9; M-1; S-1, 5.	D.K.C. MacDonald, G.K. White, and S.B. Woods (1956).


BERYLLIUM
MAGNESIUM
FIGURE 4a
G.E.-3(30°)-Be
G.E.-2(12°)-Be
G.A. - Be
G.E.-1(2°)-Be
K.S.W.-3-Mg
K.S.W.-2-Mg
K.S.W.-1-Mg
R. - Mg
M.R. - Mg
S.W. - 1 -Mg
S.W.-2-Mg
P.H.G.-1(II)-Be
P.H.G.-1(⊥)-Be
W.W.-1,2-Be
R. - Be
L. - Be
L.D.-1(⊥)-Mg
L.D.-1(II)-Mg
THERMAL CONDUCTIVITY , W/cm K
TEMPERATURE , K
50
30
20
10
8
6
4
3
2
1.0
.8
.6
.4
.3
.2
0.1
.08
.06
.05
4
6
8
10
20
40
60
80
100
200
300


THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
.01
.008
1
1.5
2
3
4
5
6
7
8
9
10
K.S.W.-2-Mg
K.S.W.-3-Mg
M.R.-Mg
R.-Mg
K.S.W.-1-Mg
S.W.-1-Mg
S.W.-2-Mg
S.-Mg-0.01%Mn
S.-Mg-0.043%Mn
S.-Mg-0.12%Mn
S.-Mg-0.29%Mn
S.-Mg-1.1%Mn
R.-Be
BERYLLIUM
MAGNESIUM
FIGURE 4b

BERYLLIUM

(See FIGURES 4a and 4b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
L.-Be	Beryllium Co. Am.; commercially pure; traces of Aℓ, Mn, Cr, Fe, Si, and Mg; total impurity 0.5%.	Physical imperfections noted.	A-5; B-1; C-1; D-1(6); E-8; F-5; G-3; L-1; M-1; S-1, 2, 3, 5.	E.J. Lewis (1929).
G.A.-Be	Degussa Co.; RRR(0°C/20.3K) = 780.	Six-sided single crystal with heat flow parallel to hexagonal axis; specimen measured in transverse magnetic fields up to 1.22 T; anisotropic effects observed. Graphs of field dependence and orientation dependence.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-3; L-1; M-1; N-2, 4; P-1; S-1, 5.	E. Grüneisen and H. Adenstedt (1938).
G.E.-1(2°), 2(12°), 3(30°)-Be	Degussa Co.; #1: RRR(0°C/20.3K) = 252. #2: RRR(0°C/20.3K) = 398. #3: RRR(0°C/20.3K) = 410.	Rod axes perpendicular to hexagonal axes; binary lateral axes inclined to rod axes by 2°, 12°, and 30°; showed anisotropy in zero field. Specimens measured in transverse magnetic fields up to 1.22 T; anisotropic effects observed. Graphs of field dependence and orientation dependence.	Same as above.	E. Grüneisen and H.-D. Erfling (1940).
. . . . .	Same specimens as the above two references.	Revises some of the values of G.A. Graphs of field dependence and orientation dependence.	Same as above plus S-2.	H.-D. Erfling and E. Grüneisen (1942).
R.-Be	Atomic Energy Research Establishment; RRR(20) = 3.52.	Semicircular ring made from compressed powder. Annealed in a vacuum for several hours at 1100°C.	A-1; B-3; C-1; D-4(2); E-4; F-4; G-2; M-1, 2; S-1.	H.M. Rosenberg (1955).
W.W.-1, 2-Be	#1: Brush Co.; 2% Mg; trace of Fe; RRR(22) = 4.57. #2: A.D. MacKay; 0.1% Mg; trace of Fe; RRR(22) = 4.12.	Sintered rods. Graphs of lattice conductivity.	A-1; B-1; C-1; D-4(2); E-1,5; F-4; G-2; L-1, 2; M-1, 4; P-1; S-1, 5.	G.K. White and S. B. Woods (1955).

BERYLLIUM (cont'd)

(See FIGURES 4a and 4b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
P.H.G.-1(∥), 1(⊥)-Be	Brush Beryllium Co. #1(∥): 98.7% Be; 1.2% BeO; 0.056% Aℓ; 0.035% Si; 0.016% Ni; 0.01% Mn; traces of B and Li; RRR = 6.01. #1(⊥): 98.7% Be; 1.18% BeO; 0.044% Aℓ; 0.014% Ni; 0.009% Mn; traces of B and Li; RRR = 4.22.	#1(∥): axis parallel to the pressing axis; not annealed or heat treated after machining. #1(⊥): perpendicular to the pressing axis; not annealed or heat treated after machining. Graph of lattice conductivity.	A-1; B-1; C-1; D-1(8); E-2, 5; F-2; G-2; L-1, 2; M-1, 4; P-2, 3; Q-1; S-1, 2, 5.	R.L. Powell, J.L. Harden, and E. F. Gibson (1960).

MAGNESIUM

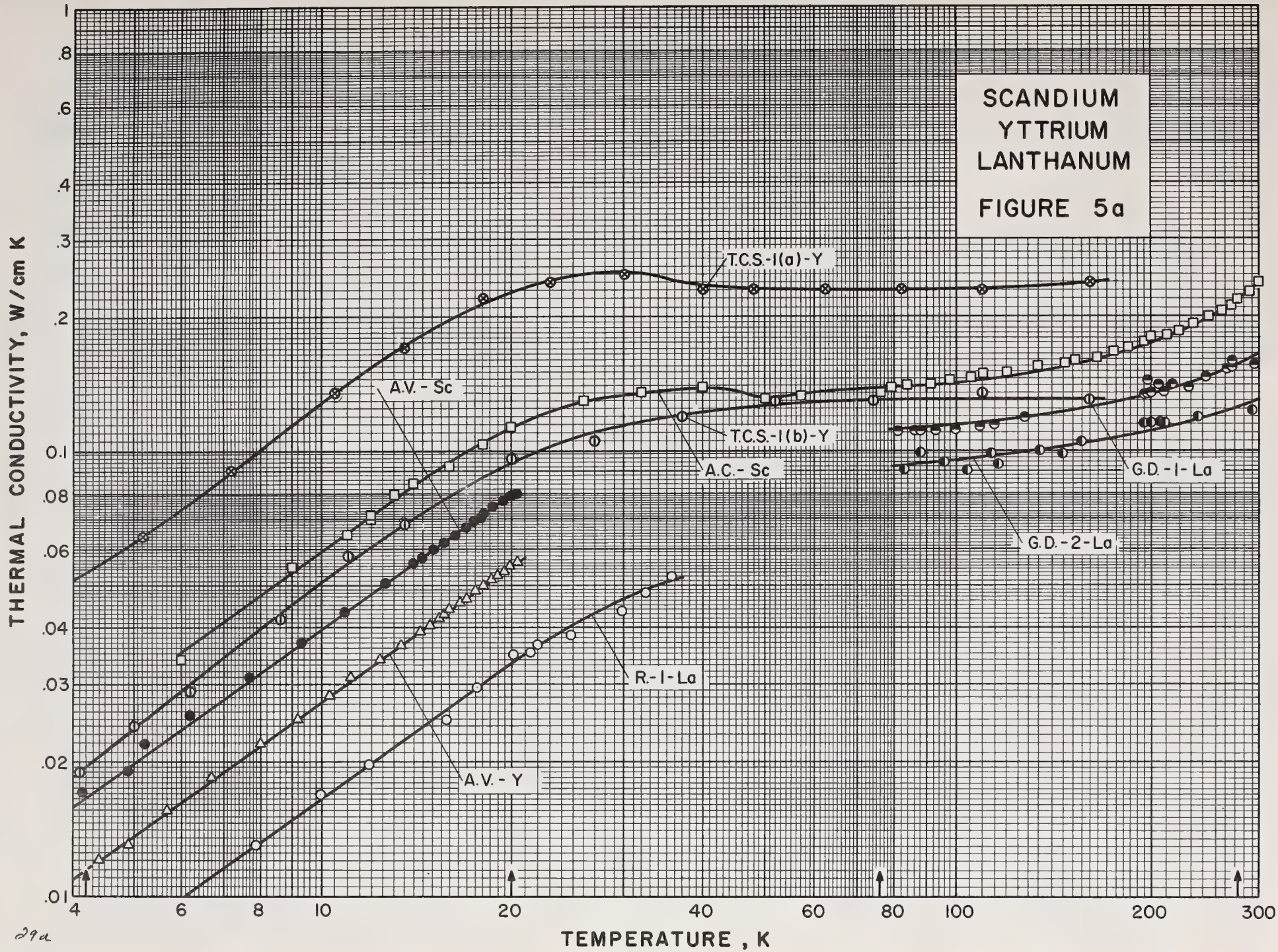
(See FIGURES 4a and 4b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	"Pure".	k = 1.57 at 0°C.	A-5; B-1; C-1; D-7(8); F-5; G-3; S-1, 3.	L. Lorenz (1881a).
. . . . .	Do.	k = 1.72 at 0°C; k = 2.0 at 80°K.	A-6; B-1; C-1; D-1(2); E-2; F-4; G-3; S-1, 5.	J. Staebler (1929).
. . . . .	Do.	k = 1.72 at 0°C; k = 1.87 at 80°K.	A-1; B-1; C-1; D-1(2); E-2; F-4; G-3; S-1, 5.	W. Mannchen (1931).
. . . . .	Do.	k = 1.60 at 18°C.	A-1; B-1; C-3; D-1(2); F-4; G-3; S-1, 5.	R. Kikuchi (1932).
M.R.-Mg	Johnson, Matthey; 99.95% pure.	. . . . .	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1.	K. Mendelssohn and H. Rosenberg (1952a).
S.-Mg-0.01% 0.043%, 0.12% 0.29%, 1.1% Mn	Dow; manganese impurities as marked on graph.	. . . . .	M-1, 2; S-1, 5.	E.G. Sharkoff (1952, 1953a, b).
K.S.W.-1, 2, 3-Mg.	Johnson, Matthey 1848, 99.98% pure; 0.013% Fe; 0.0023% Mn; 0.0013% Pb; trace of Si, Cu, Ag, Ca, Na.	#1: as drawn. #2 and #3: annealed in vacuum 3 hrs. at 350°C.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1.	W.R.G. Kemp, A. K. Speedhar and G.K. White (1953).
R.-Mg	Johnson, Matthey 1703; 99.95% pure; 0.03% Mn; 0.0075% Fe; 0.004% Al; RRR(20) = 140.	Annealed 6 hrs.in vacuum at 500°C.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1, 2; N-8; S-1, 5.	H.M. Rosenberg (1954 a, 1955).

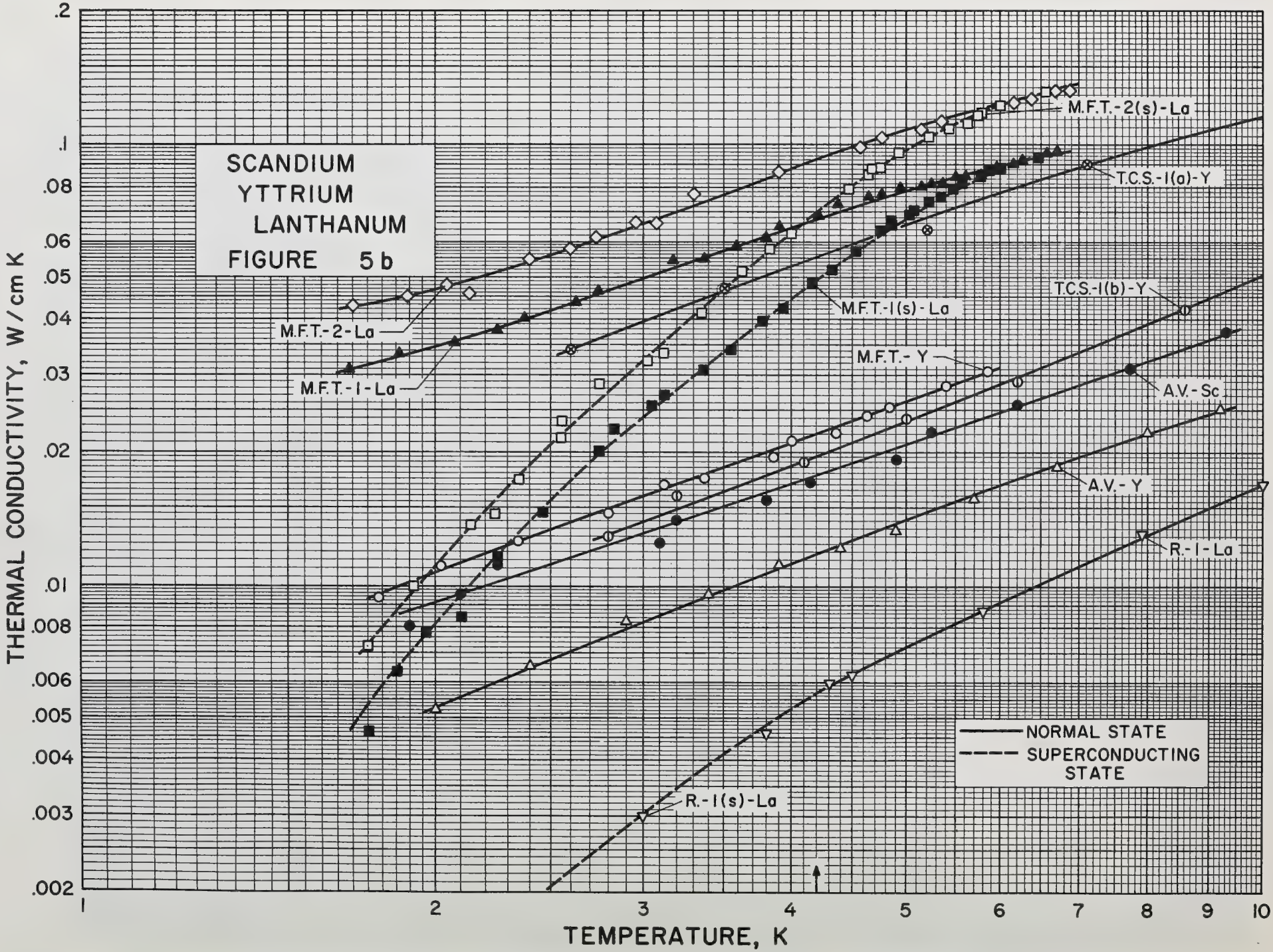
MAGNESIUM (cont'd)

(See FIGURES 4a and 4b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	See next reference.	. . . . .	P.B. Alers, D. A. Spohr, and R. T. Webber (1955).
S.W.-1,2-Mg	#1: Johnson, Matthey; 99.98% pure; 0.013% Fe; 0.0023% Mn; 0.0013% Pb; trace of Ag, Aℓ, Ca, Cu, Na, and Si; RRR(27) = 73. #2: Dow Chemical Co.; 99.95% pure; 0.043% Mn; 0.0048% Zn; 0.0012% Ca; 0.0011% Pb; 0.0011% Sn; 0.0010% Fe; 0.001% Si; 0.0002% Aℓ; 0.0001% Cu; and 0.0001% Ni; RRR(27) = 41.	#1: extensively cold-worked, causing a 14% reduction in diameter. No change in sample purity after swaging. There were a few crystallites ranging in size up to 0.1mm. #2: hot-extruded by supplier, then annealed for 24 hrs. at 300°C, then rapidly quenched in water at 40°C. Both specimens show electrical resistivity minimum at 5 and 15 K, respectively. Graph of #1 for WT versus T^3.	A-1; B-1; C-1; D-3(2); E-4,5; F-4; G-2; L-1,2; M-1,2; P-1; S-1,5.	D. A. Spohr and R. T. Webber (1957).
L.D.-1(∥), 1(⊥)-Mg	Dow Chemical Co.; AN-M-29.	Received as hot-rolled; annealed 1 hr at 600°F and furnace cooled. #1(∥): specimen axis parallel to rolling direction. #1(⊥): specimen axis perpendicular to rolling direction. Anisotropy observed.	A-6; B-1; C-2; D-1(7); E-1; F-2; G-2; S-1,3-6.	C.F. Lucks and H. W. Deem (1958).


SCANDIUM
YTTRIUM
LANTHANUM
FIGURE 5a
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
T.C.S.-1(a)-Y
A.V. - Sc
T.C.S.-1(b)-Y
A.C. - Sc
G.D. - 1 - La
G.D. - 2 - La
R. - 1 - La
A.V. - Y
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
.01
4
6
8
10
20
40
60
80
100
200
300

29a


SCANDIUM
YTTRIUM
LANTHANUM
FIGURE 5 b
THERMAL CONDUCTIVITY, W / cm K
TEMPERATURE, K
.2
.1
.08
.06
.05
.04
.03
.02
.01
.008
.006
.005
.004
.003
.002
1
2
3
4
5
6
7
8
9
10
M.F.T.-2(s)-La
T.C.S.-1(a)-Y
T.C.S.-1(b)-Y
M.F.T.-1(s)-La
M.F.T.-2-La
M.F.T.-Y
M.F.T.-1-La
A.V.-Sc
A.V.-Y
R.-1-La
R.-1(s)-La
NORMAL STATE
SUPERCONDUCTING STATE

SCANDIUM

(See FIGURES 5a and 5b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
A. C. -Sc	St. Eloi Corp.; 99.9% pure; major impurity is Ta; less than 0.1% Y; trace of Si, Zr, Ca, and Fe; RRR = 5.3.	Grain diameters 0.14 to 0.22 mm. Thermal conductivity minimum observed at 50 K. Graph of non-electronic contributions to thermal conductivity.	A-1; B-1; C-1; D-1(2); E-1; F-4; G-2; L-1, 2; M-1; P-1, 2, 4, 6; Q-1; S-1, 5.	A. Arajs and R. V. Colvin (1965).
A. V. -Sc	Approximately 99.9% pure; RRR(20) = 9.59.	. . . . .	B-4; M-1; P-1; S-1, 5.	N. G. Aliyev and N. V. Volkenshteyn (1965).
. . . . .	Johnson, Matthey; high purity.	k = 0.157 at 18°C; average value of two-ball and direct reading thermal comparators.	A-6; B-2; D-1(2); F-5; G-3; S-1, 5.	R. W. Powell and B. W. Jolliffe (1965).
. . . . .	Johnson, Matthey; high purity; < 0.01% other rare-earth metals; ~ 0.01% other base metals.	Same as above. Sublimed in vacuum; reduced from its flouride with Li or Ca. Graph of Lorenz number versus atomic number. Graph of lattice component versus atomic number.	Same as above.	B. W. Jolliffe, R. P. Tye, and R. W. Powell (1966).

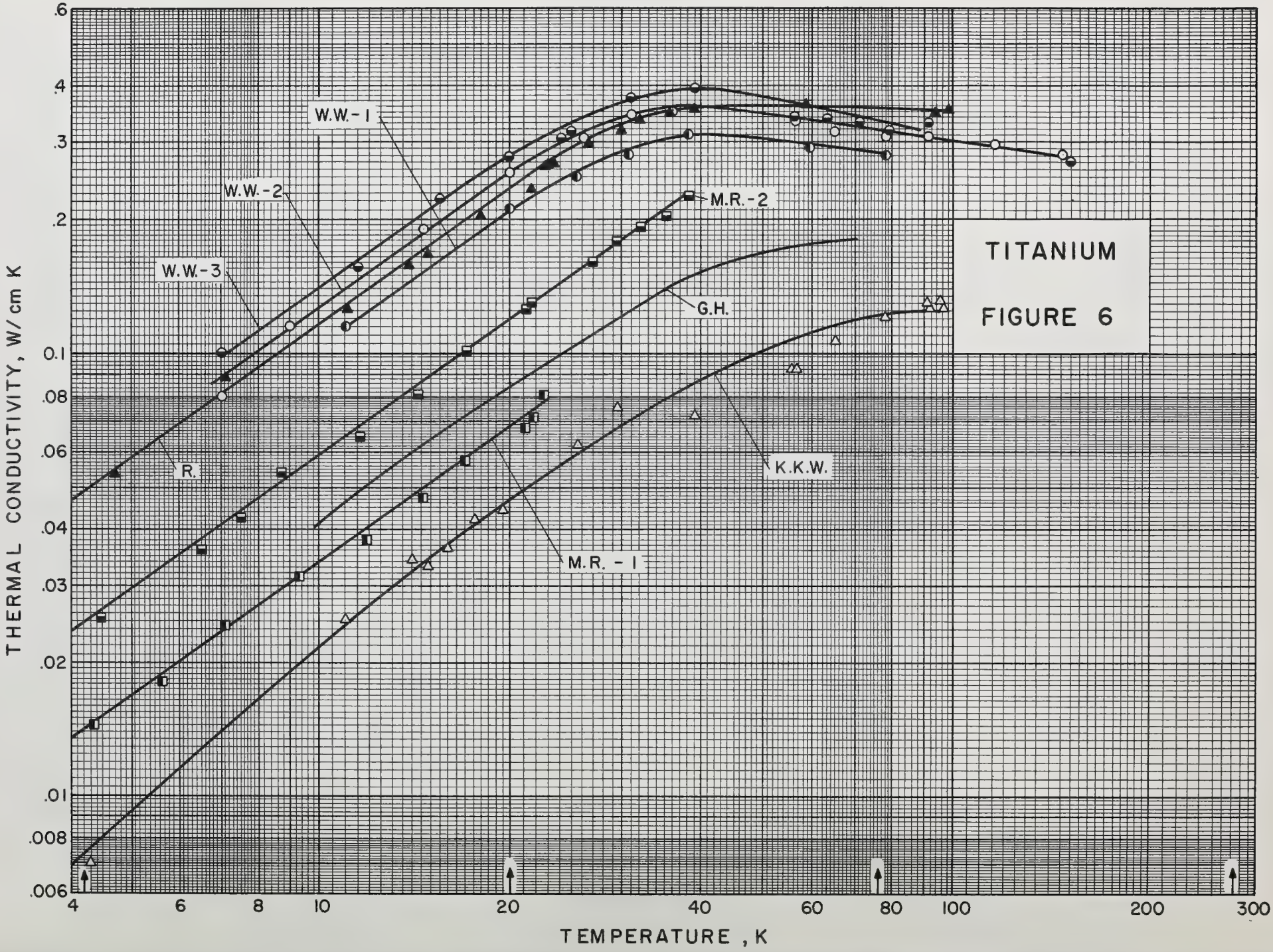
YTTRIUM

(See FIGURES 5a and 5b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
M.F.T.-Y	99.99% nominal purity; RRR (20) = 13.0.	Machined from a zone refined ingot, then annealed in vacuum at 1150°C for 75 hrs. Values did not vary within experimental error when measured in a transverse field of 0.66 T.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-2; M-1; N-2; S-1, 5.	T. Mamiya, T. Fukuroi, and S. Tanuma (1965).
A.V.-Y	Approximately 99.9% pure; RRR(20) = 7.3.	. . . . .	B-4; M-1; P-1; S-1, 5.	N.G. Aliyev and N.V. Volkenshteyn (1965).
. . . . .	Johnson, Matthey; high purity; ~ 0.1% Ta; < 0.1% other rare-earth metals; ~ 0.03% other base metals.	k = 0.159 at 18°C; average value of two-ball and direct reading thermal comparators. Reduced from its flouride with Li or Ca; remelted in vacuum.	A-6; B-1; D-1(2); F-5; G-3; S-1, 5.	B.W. Jolliffe, R. P. Tye, and R. W. Powell (1966).
T.C.S.-1(a), 1(b)-Y	#1(a): RRR(20) = 14.5. #1(b): RRR(20) = 8.9. 0.15% O_2; 0.12% N_2; 0.01% Gd; 0.002% Cu; 0.001% Fe; < 0.001% Dy, H_2, Ho, and Tb; local inclusions of Si.	Zone melted in vacuum. Single crystals. #1(a): oriented parallel; #1(b): oriented perpendicular to the principal axis of crystal.	A-1; B-1; C-1; D-1(2), 3(2); E-5; F-4; G-2; L-1; M-1; N-4; S-1, 2, 5.	P.V. Tamarin, G.E. Chuprikov, and S. S. Shalyt (1969).

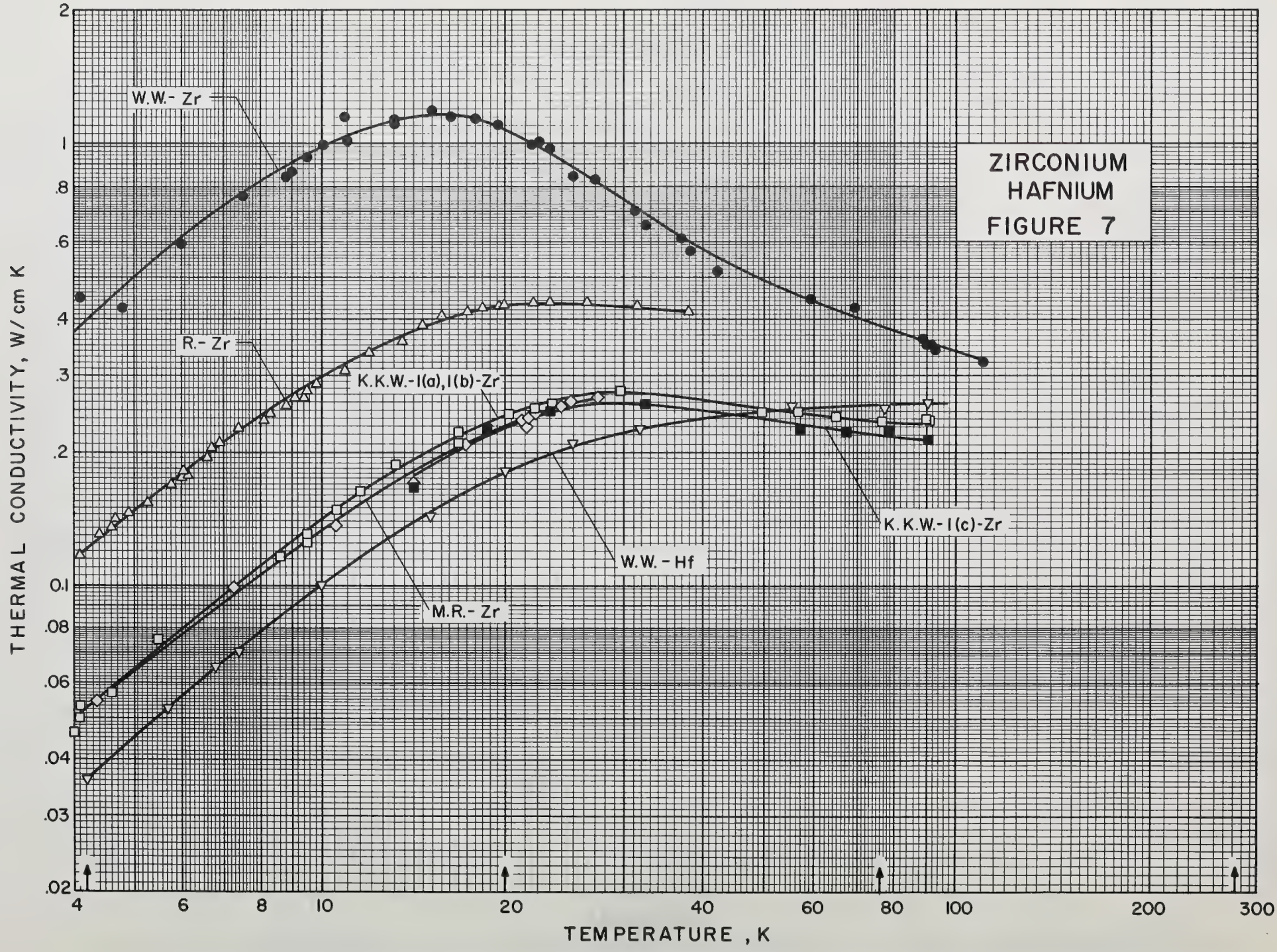
LANTHANUM
(See FIGURES 5a and 5b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
R-1,1(s)-La	Iowa State University; purity better than 99.94%; largest impurities Ca and Be; RRR (20) = 3.75.	Unannealed. $T_c \sim 4.7$K; below 4.7K specimen in a field of 0.33 T, in intermediate state.	A-1; B-2; C-1; D-4(2); E-4; F-4; G-2; M-1; N-3; S-1.	H.M. Rosenberg (1955).
M.F.T.-1,1(s) -La	H. Fleishman, Ltd.; 99.99% nominal purity; RRR(20) = 32.4.	Vacuum annealed at 600°C for 24 hrs. Trace of hcp phase dispersed in the fcc phase. Measured in both normal and superconducting (s) states. Normal state field of 0.66 T. Graph of WT versus T^3. Graph of ratio of superconducting to normal thermal conductivity.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-2; L-1,2; M-1; N-2, 3; S-1,5.	T. Mamiya, T. Fukuroi, and S. Tanuma (1965).
M.F.T.-2,2(s) -La	Same as above; a little purer than #1; RRR(20) = 44.0.	Vacuum annealed at 600°C for 106 hrs. Trace of hcp phase dispersed in the fcc phase. Measured in both normal and superconducting (s) states. Normal state field of 0.66 T. Graph of thermal conductivity versus magnetic field up to 0.9 T, five isotherms.	Same as above.	Same as above.
. . . . .	Johnson, Matthey; high purity; < 0.01% other rare earth metals; ~ 0.02% other base metals.	Remelted in vacuum. k = 0.140 at 18°C, obtained by using direct reading thermal comparator.	A-6; B-2; D-1(2); F-5; G-3; S-1,5.	B.W. Jolliffe, R. P. Tye, and R.W. Powell (1966).
G.D.-1,2-La	#1: 0.1% O_2; 0.01% Ce; 0.008% Fe; 0.005% Cu; 0.005% Nd; 0.005% Pr. #2: 0.5% Nd; 0.25% Ca; 0.15% Ta; 0.1% Ce; 0.04% Fe; 0.005% Cu.	#1: electron beam refined. #2: from lot 499. Hexagonal structure, no cubic. Graph of lattice conductivity.	A-1; B-2; C-1; D-1(2); E-1; F-4; G-3; L-1; M-1; O-1; P-1; Q-1; S-1,2,5.	A. V. Golubkov, E. D. Devyatkova, V. P. Zhuze, V.M. Sergeeva, and I. A. Smirnov (1966).


TITANIUM
FIGURE 6
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
.6
.4
.3
.2
0.1
.08
.06
.04
.03
.02
.01
.008
.006
4
6
8
10
20
40
60
80
100
200
300
W.W.-1
W.W.-2
W.W.-3
M.R.-2
G.H.
R.
K.K.W.
M.R.-1

TITANIUM
(See FIGURE 6)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	Commercially pure.	Abstract only. k = 0.20 at 273K; k = 0.21 at 195 K; k = 0.18 at 90 K; k = 0.12 at 20 K.	. . . . .	C. J. Rigney and L. I. Bochstahler (1951).
M.R.-1, 2	Assoc. Elect. Ind. Res. Lab., England. #1: 99.9% pure; RRR(20) = 6.32. #2: 99.99% pure; RRR(20) = 10.1.	#2: annealed in vacuum for 20 hrs. Thermal conductivity linear down to 2 K. Some results included in the next reference.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1; S-5.	K. Mendelssohn and H. M. Rosenberg (1952b).
R.	Assoc. Elect. Ind. Res. Lab., England; O_2 and N_2 impurity about 0.01%.	Single crystal; Vickers pyramid hardness = 94. Thermal conductivity linear down to 2.2 K.	Same as above plus S-1.	H. M. Rosenberg (1955).
K.K.W.	Johnson, Matthey 4233; 98% nominal purity; 1.63% O_2; 0.14% C; 0.13% Si; 0.081% Ni; 0.05% Fe; 0.024% Mg; RRR (20) = 2.96.	Annealed at 950°C for 5 hrs. in a vacuum. Thermal conductivity linear down to 2 K. Specimen measured twice with different connectors.	A-1; B-1; C-1, 2; D-4(2); E-2, 5; F-4; G-2; L-1, 2; M-1; N-5; P-1; S-1, 5.	W. R. G. Kemp, P. G. Klemens, and G. K. White (1956).
W.W.-1, 2, 3	University of Toronto; 99.99% pure; 0.005% Si; 0.002% N_2 and O_2; 0.001% C; 0.01% total of Cr, Cu, Fe, Mg, and Mn. #1: RRR(22)=16.4. #2:RRR(22) = 18.3. #3: RRR(22)= 21.9.	#1: as rolled. #2 and #3: vacuum (10^{-6} Torr) annealed at 800°C for 60 hrs. Table of intrinsic thermal resistivity.	A-1; B-1; C-1; D-4(2); E-1,5; F-4; G-1; L-1, 2; M-1; N-5; P-1; Q-1; S-1, 5.	G. K. White and S. B. Woods (1959).
. . . . .	William Jessop & Sons; "very high purity."	k = 0.22 at 20°C. DPN hardness of 58-62.	A-6; B-1; C-1; D-1(2); E-1; F-4; G-3; L-1; P-1; S-1, 5.	R. W. Powell and R. P. Tye (1961).
See FIGURE 69	. . . . .	Measured below 1 K.	. . . . .	G. Davey and K. Mendelssohn (1963).
G.H.	99.9% pure.	. . . . .	A-1; B-1; C-1; D-2(2); F-4; G-2; L-1; M-1.	C. Gladun and W. Holzhäuser (1964).


ZIRCONIUM
HAFNIUM
FIGURE 7
W.W.- Zr
R.- Zr
K.K.W.-I(a),I(b)-Zr
K.K.W.-I(c)-Zr
W.W. - Hf
M.R.- Zr
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE , K
2
1
.8
.6
.4
.3
.2
0.1
.08
.06
.04
.03
.02
4
6
8
10
20
40
60
80
100
200
300

ZIRCONIUM

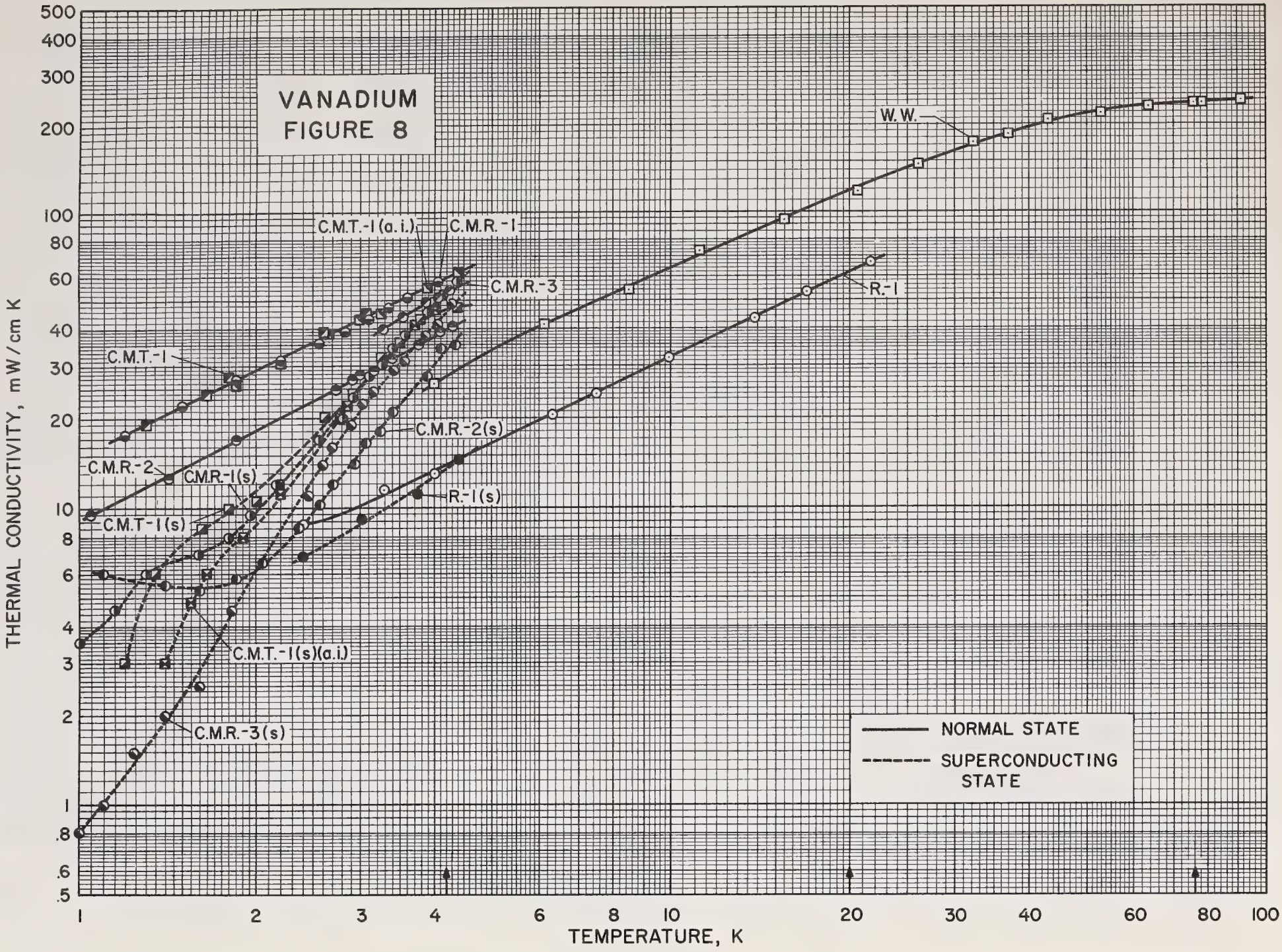
(See FIGURE 7)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
M.R.-Zr	Johnson, Matthey 3062; ~ 98% pure; about 2% Hf impurity; RRR(20) = 21.2.	Annealed at 1150°C in a vacuum. Thermal conductivity linear down to 2 K. Some results included in the next reference.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1.	K. Mendelssohn and H.M. Rosenberg (1952b).
R.-Zr	Metropolitan Vikers; ~ 98% pure; about 2% Hf impurity; RRR(20) = 42.5.	Annealed; prepared by the Van Arkel process. Large crystallites were visible.	Same as above plus S-1, 5.	H.M. Rosenberg (1955).
K.K.W.-1(a), 1(b), 1(c)-Zr	Johnson, Matthey 5000; 99.99% nominal purity; Fe, and Hf, Ni, Si, Ti, Cr, Al, Cu, Mg (faintly visible spectral lines); RRR(20) = 24.2.	Annealed at 950°C for 5 hrs in a vacuum. (a, b, c) indicates mounting in a cryostat with copper fittings, current lead removed, and mounting by means of drilled holes and tapping, respectively. Apparently the strains induced by drilling and tapping have lowered the thermal conductivity of 1(c).	A-1; B-1; C-1; D-4(2); E-2, 5; F-4; G-2; L-1, 2; M-1; N-5; P-1; S-1, 5.	W.R.G. Kemp, P. G. Klemens, and G.K. White (1956).
W.W.-Zr	Oak Ridge National Lab.; 99.95% pure; 132 ppm Hf; 79 ppm C; 24 ppm Fe; 11 ppm Ni; 21-50 ppm O_2; 3-50 ppm N_2; < 100 ppm Zn and P; 2-7 ppm Ca, Cr, Mo, Si, and H_2; < 10 ppm of 18 others; RRR(22) = 168.	Annealed in a vacuum (10^{-6} Torr). Specimen was composed of four wires. Vickers hardness 58. Arc cast, anneal at 1100°C for 4 hours, swaged, annealed at 1000°C for 15 min, annealed at 800°C in a vacuum of 10^{-6} Torr for 15 min. Two separate runs with change in clamps. Table and graph of intrinsic thermal resistivity.	A-1; B-1; C-1; D-4(2); E-1, 5; F-4; G-1; L-1, 2; M-1; N-5; P-1; Q-1; S-1, 5.	G.K. White and S. B. Woods (1959).

HAFNIUM

(See FIGURE 7)

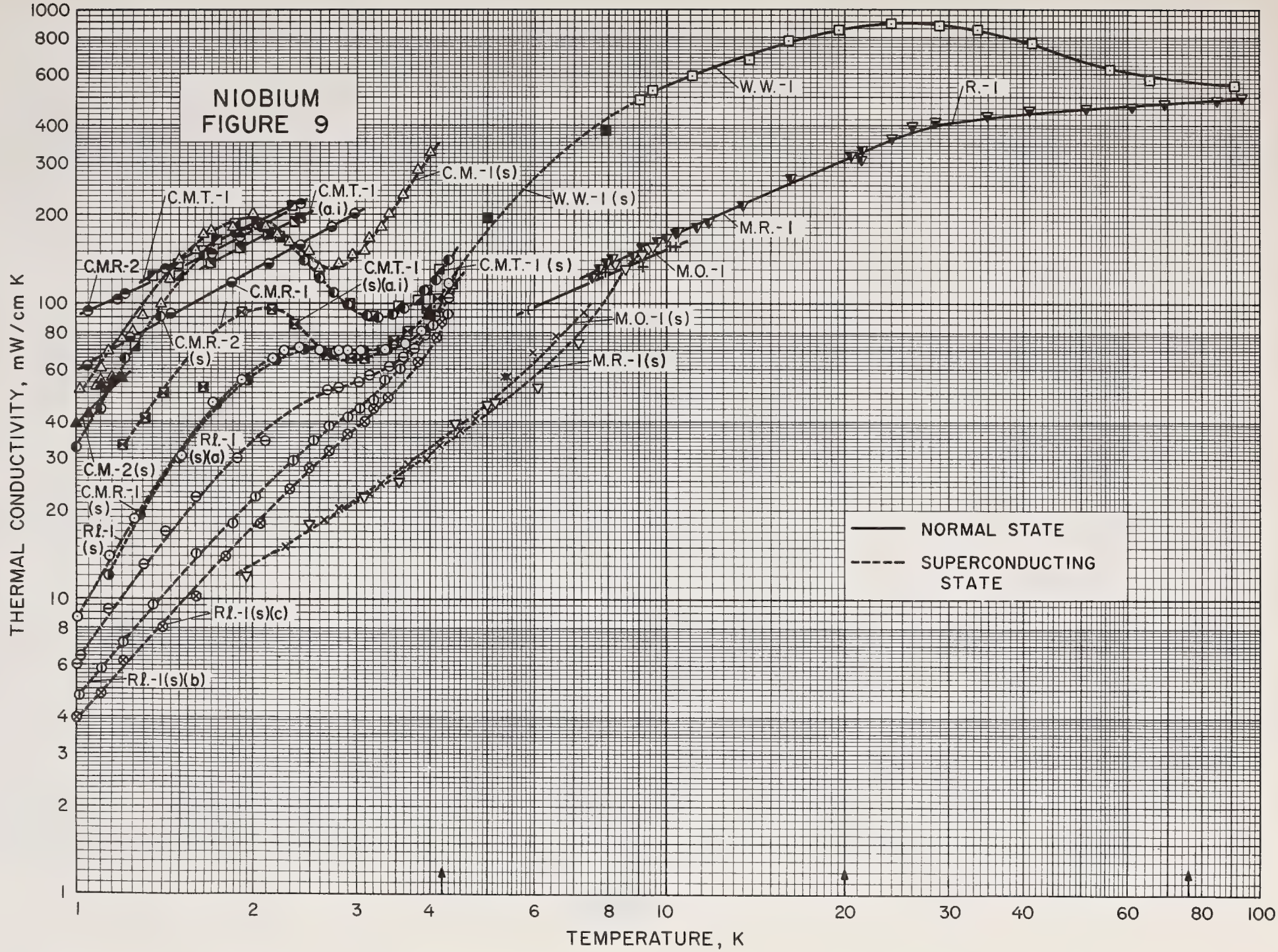
CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
W.W.-Hf	Foote Mineral Co.; 0.5-1% Zr; RRR(22) = 8.6.	As received.	A-1; B-1; C-1; D-4(2); E-1,5; F-4; G-1; L-1,2; M-1; P-1; S-1.	G.K. White and S. B. Woods (1957d).


VANADIUM
FIGURE 8
THERMAL CONDUCTIVITY, mW/cm K
TEMPERATURE, K
W.W.
C.M.T.-1(a.i.)
C.M.R.-1
C.M.R.-3
C.M.T.-1
C.M.R.-2(s)
C.M.R.-2
C.M.R.-1(s)
R.-1
R.-1(s)
C.M.T.-1(s)
C.M.T.-1(s)(a.i.)
C.M.R.-3(s)
NORMAL STATE
SUPERCONDUCTING STATE

VANADIUM

(See FIGURE 8)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
R.-1, 1(s)	Johnson, Matthey; RRR(20)= 3.22.	Unannealed wire. Both normal and superconducting (s) states.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1; N-3; S-1.	H. M. Rosenberg (1955).
W.W.	Electrometallurgical Company; ~ 99.9% pure; RRR(22)= 5.1.	Annealed at 1300°C in vacuum. Graph of intrinsic thermal resistivity.	A-1; B-1; C-1; D-4(2); E-1, 5; F-4; G-1; L-1, 2; M-1; P-1; S-1, 5.	G. K. White and S. B. Woods (1957d).
C.M.T.-1, 1(s), 1(a.i.), 1(s) (a.i.)	. . . . .	Single crystal rod. Specimen first measured in both normal and superconducting (s) states. Then, after irradiation (a.i.) to a dose of 10^{18} fast neutrons cm^{-2} at 30 ± 5°C and allowing a few weeks for radioactivity to decay, the normal 1(a.i.) and superconducting 1(s)(a.i.) states were measured.	A-1; B-1; C-1; D-3(2); F-4; G-2; M-1, 2; N-3; P-2, 3.	K. D. Chaudhuri, K. Mendelssohn, and M. W. Thompson (1960).
C.M.R.-1, 1(s), 2, 2(s), 3, 3(s)	Johnson, Matthey. #1: 0.2% Fe; 0.02% Si; 0.01% Mn; 0.005% Cu; 0.002% Ti and Mo(weight); RRR(22)= 13.8. #2: 0.05% Fe; 0.01% Si; 0.005% Mo; 0.0005% Mn; 0.0003% Cu(weight); RRR (22)= 20.2. #3: 0.41% Y; 0.09% Fe; 0.08% N_2; 0.05% C; 0.01% Si; < 0.01% O_2(weight); RRR(22)= 18.2	#1 and #2: single crystals; prepared by floating zone melting. "High carbon and gas content." Diamond pyramid hardness: 185 and 160, respectively. Measured in both normal and superconducting (s) states. #3: severely work-hardened polycrystal. Measured in both normal and superconducting (s) states. In normal state, specimen measured in field of 0.46 T down to 3.5 K; below this in a field of 0.62 T. Graph of reduced thermal conductivity as a function of reduced temperature.	A-1; B-1; C-1; D-3(2); E-5, 6; F-4; G-2; M-1; N-2, 3; P-1.	A. Calverly, K. Mendelssohn, and P. M. Rowell (1961). (Preliminary results reported in K. Mendelssohn (1958).)
. . . . .	. . . . .	Additional interpretation of specimen C.M.T.-1. Graph of $\ell n\, k_s$ as a function of inverse reduced temperature.	. . . . .	K. D. Chaudhuri (1962).


NIOBIUM
FIGURE 9
THERMAL CONDUCTIVITY, mW/cm K
TEMPERATURE, K
NORMAL STATE
SUPERCONDUCTING STATE
W.W.-1
R.-1
C.M.-1(s)
W.W.-1(s)
C.M.T.-1
C.M.T.-1 (a.i)
C.M.T.-1 (s)
C.M.T.-1 (s)(a.i)
M.R.-1
M.O.-1
M.O.-1(s)
M.R.-1(s)
C.M.R.-2
C.M.R.-1
C.M.R.-2 (s)
Rℓ.-1 (s)(a)
C.M.-2(s)
C.M.R.-1 (s)
Rℓ.-1 (s)
Rℓ.-1(s)(c)
Rℓ.-1(s)(b)

NIOBIUM

(See FIGURE 9)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
M.O.-1, 1(s)	Hilger; "high purity"; No. 1919.	Apparatus described by J. L. Olsen (1952) for results on lead alloys. Measured in both normal and superconducting (s) states. Graph of hysteresis in a magnetic field. Element referred to as Columbian.	G-2; N-2, 3.	K. Mendelssohn and J. Olsen (1950 a).
M.R.-1, 1(s)	Johnson, Matthey 4526; 99.99% pure.	Measured in transverse field of 0.23 and 0.33 T. Measured in both normal and superconducting (s) states. Graph of thermal conductivity as a function of magnetic field and temperature. Element referred to as Columbian.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; N-2, 3; Q-1.	K. Mendelssohn and H. Rosenberg (1952 b).
See FIGURE 70	Same as M.R.	Superconducting state below 1 K.	. . . . .	K. Mendelssohn and C. A. Renton (1953, 1955).
R.	Johnson, Matthey 4526; 99.99% pure; RRR(20) = 10.4.	Unannealed. Continuation of M.R.-1 curve. T_c = 9.22 K. Graph of thermal conductivity as a function of magnetic field and temperature. Element referred to as Columbian.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1; N-2, 3; Q-1; S-1, 5.	H.M. Rosenberg (1955).
W.W.-1, 1(s)	Fansteel Metallurgical Corp.; > 99.9% pure; RRR(22)= 33.	Drawn, then annealed in high vacuum through self-heating by an electrical current. Ductile. Measured in both normal and superconducting (s) states. T_c = 9.25. Graph of intrinsic thermal resistivity.	A-1; B-1; C-1; D-4(2); E-1,5; F-4; G-1; L-1, 2; M-1; N-3; S-1, 5.	G.K. White and S.B. Woods (1957 d).
. . . . .	. . . . .	Two crystals measured in normal and superconducting states and under varying degrees of strain. See A. Calverly, K. Mendelssohn, and P. M. Rowell (1961) below.	. . . . .	K. Mendelssohn (1958).
Rℓ.-1(s), 1(s) (a), 1(s) (b), 1(s) (c)	Johnson, Matthey; 3 ppm Cu and Mg (weight).	Zone refined single crystal; unannealed. Measured in the superconducting (s) state under no strain and increasing degrees of strain: (a) 51% strain; (b) 134% strain; (c) 195% strain. Graph of thermal conductivity as a function of temperature and four degrees of strain.	A-1; B-1; C-1; D-3(2); E-5,6; F-4; G-2; P-2, 3, 4.	P.M. Rowell (1960).

NIOBIUM (cont'd)

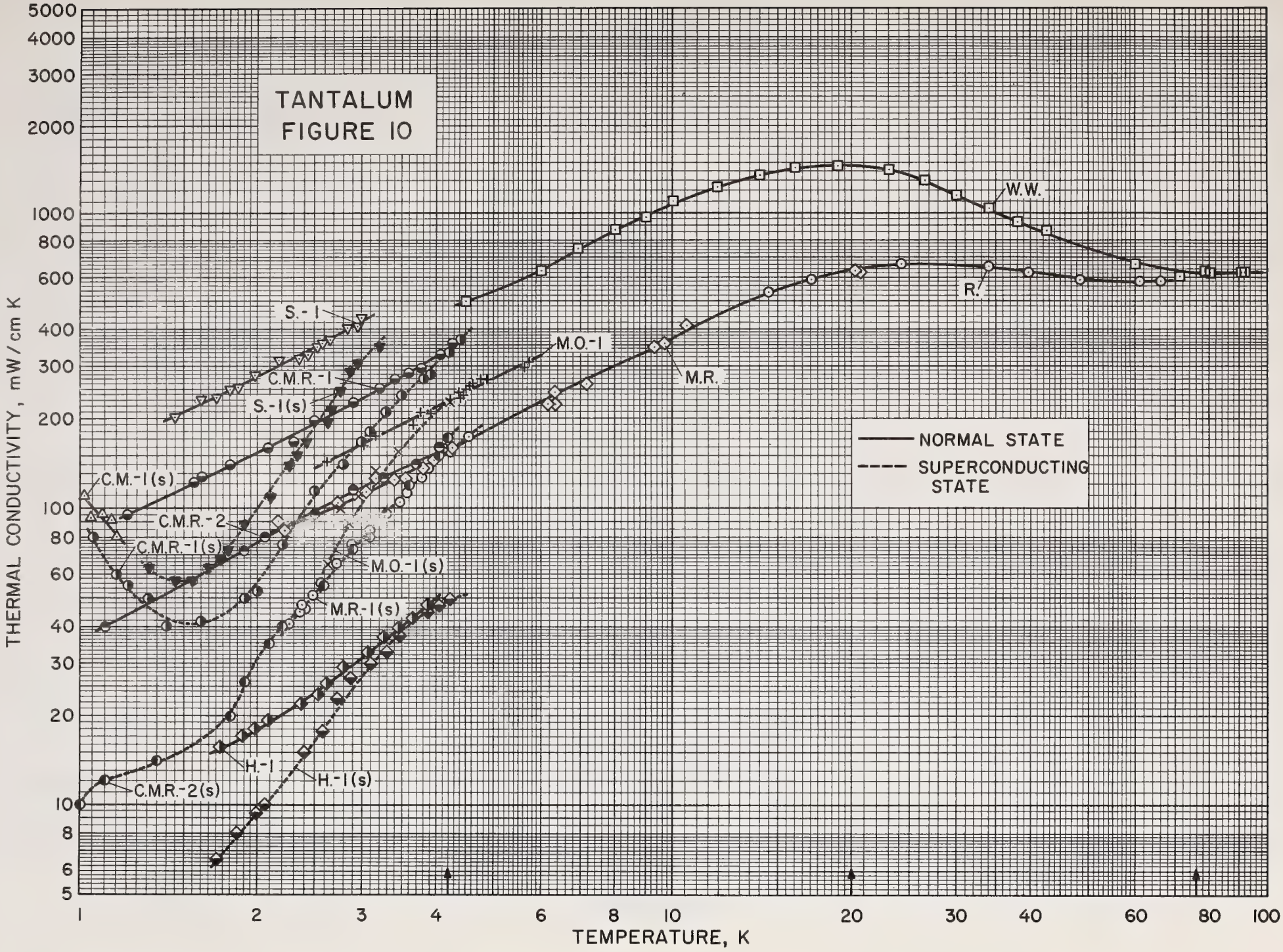
(See FIGURE 9)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
C.M.T.-1, 1(s), 1(a.i.), 1(s) (a.i.)	. . . . .	Single crystal rod. Specimen first measured in both normal and superconducting (s) states. Then, after irradiation (a.i.) to a dose of 10^{18} fast neutrons cm^{-2} at 30 ± 5°C and allowing a few weeks for radioactivity to decay, the normal 1 (a.i.) and superconducting 1(s) (a.i.) states were measured.	A-1; B-1; C-1; D-3(2); F-4; G-2; M-1, 2; N-3; P-2, 3.	K.D. Chaudhuri, K. Mendelssohn, and M.W. Thompson (1960).
C.M.R.-1, 1(s), 2, 2(s)	Same stock material as Rℓ.	Single crystals; prepared by floating zone melting. Diamond pyramid hardness - #1: 75; #2: 66. T_c = 9.0 ± 0.1 K. Measured in normal, intermediate, and superconducting (s) states. Graph of thermal conductivity as a function of transverse magnetic field at three fixed temperatures.	A-1; B-1; C-1; D-3(2); E-5, 6; F-4; G-2; M-1; N-2, 3; P-3.	A. Calverly, K. Mendelssohn, and P. M. Rowell (1961).
C.M.-1 (s), 2 (s); see also FIGURE 70	Same stock material as Rℓ. #1: RRR(20)= 120. #2: RRR(20)= 60.5.	Prepared same as C.M.R. Measured in the superconducting (s) state down to 0.2 K. Graph of the ratio of superconductive to normal thermal conductivity as a function of reduced temperature. Graph of phonon mean-free-path as a function of reduced temperature.	A-1; B-1; C-1; D-3(2); E-5, 6; F-4; G-2; M-2; N-3; P-4, 5; Q-1.	A. Connolly and K. Mendelssohn (1962).
. . . . .	. . . . .	Measured in the normal, intermediate, and superconducting states. Graph of thermal conductivity as a function of magnetic field and temperature before and after irradiation by 5.7×10^{17} neutrons cm^{-2} of energy greater than 1 Mev.	. . . . .	G. Kuhn (1962).
. . . . .	5.0% Ta; 0.17% W; 0.054% Fe; 0.04% Mo; 0.014% Si and Ti; 0.013% C.	k = 450 mW/cm-K at 273 K. Specimen was sintered from electrolytic powder in vacuum (10^{-3} Torr) for 5 hrs. at 1373 K, and 5 hrs. at 2623 K; refined twice by zone melting.	A-4; B-1; C-3; G-3.	N.Z. Pozdnyak and K.G. Akhmetzyanov (1963).

NIOBIUM (cont'd)

(See FIGURE 9)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	Measured the thermal conductivity of niobium in the normal, mixed, and superconducting states; the values are approximately the same as W. W. -1. The lattice and electronic components were separated.	. . . . .	S. M. Wasim and N. H. Zebouni (1969).
. . . . .	. . . . .	Measured the thermal conductivity of niobium in the normal and superconducting states.	. . . . .	B. A. Merisov and V. I. Khotkevich (1969).
. . . . .	. . . . .	Measured the thermal conductivity of niobium in the temperature range 1. 8-9. 2 K in zero field and in longitudinal and transverse magnetic fields up to 0. 4T. In zero field: k = 10. 5 W at 4. 1 K in normal state; k = 3. 8 W at 4. 1 K in superconducting state.	. . . . .	K. Noto (1969).
. . . . .	Specimen # 1, RRR = 2000, < 10^2 ppm(atomic)Ta; #2, RRR = 26, 10^4 ppm Ta.	Measured two single-crystal specimens between 0. 04 and 4 Kelvin. Specimen #1, K = 0. 1 W/cm K at 1 K, 0. 7 W/cm K at 2. 5 K. Specimen #2, K = 0. 04 at 1 K, 0. 12 at 2 K, 0. 06 at 3. 2 K, 0. 07 at 4 K. See also Low Temperature Tables.	A-1; B-1; C-1; D-3(2); E-5, 6; F-4; G-2; M-1; N-3; P-5; Q-1.	A. C. Anderson, C. B. Satterthwaite, and S. C. Smith (1971).


TANTALUM
FIGURE 10
THERMAL CONDUCTIVITY, mW/cm K
TEMPERATURE, K
5000
4000
3000
2000
1000
800
600
400
300
200
100
80
60
40
30
20
10
8
6
5
1
2
3
4
6
8
10
20
30
40
60
80
100
W.W.
R.
M.R.
M.O.-1
S.-1
C.M.R.-1
S.-1(s)
C.M.-1(s)
C.M.R.-2
C.M.R.-1(s)
M.O.-1(s)
M.R.-1(s)
H.-1
H.-1(s)
C.M.R.-2(s)
NORMAL STATE
SUPERCONDUCTING STATE

TANTALUM

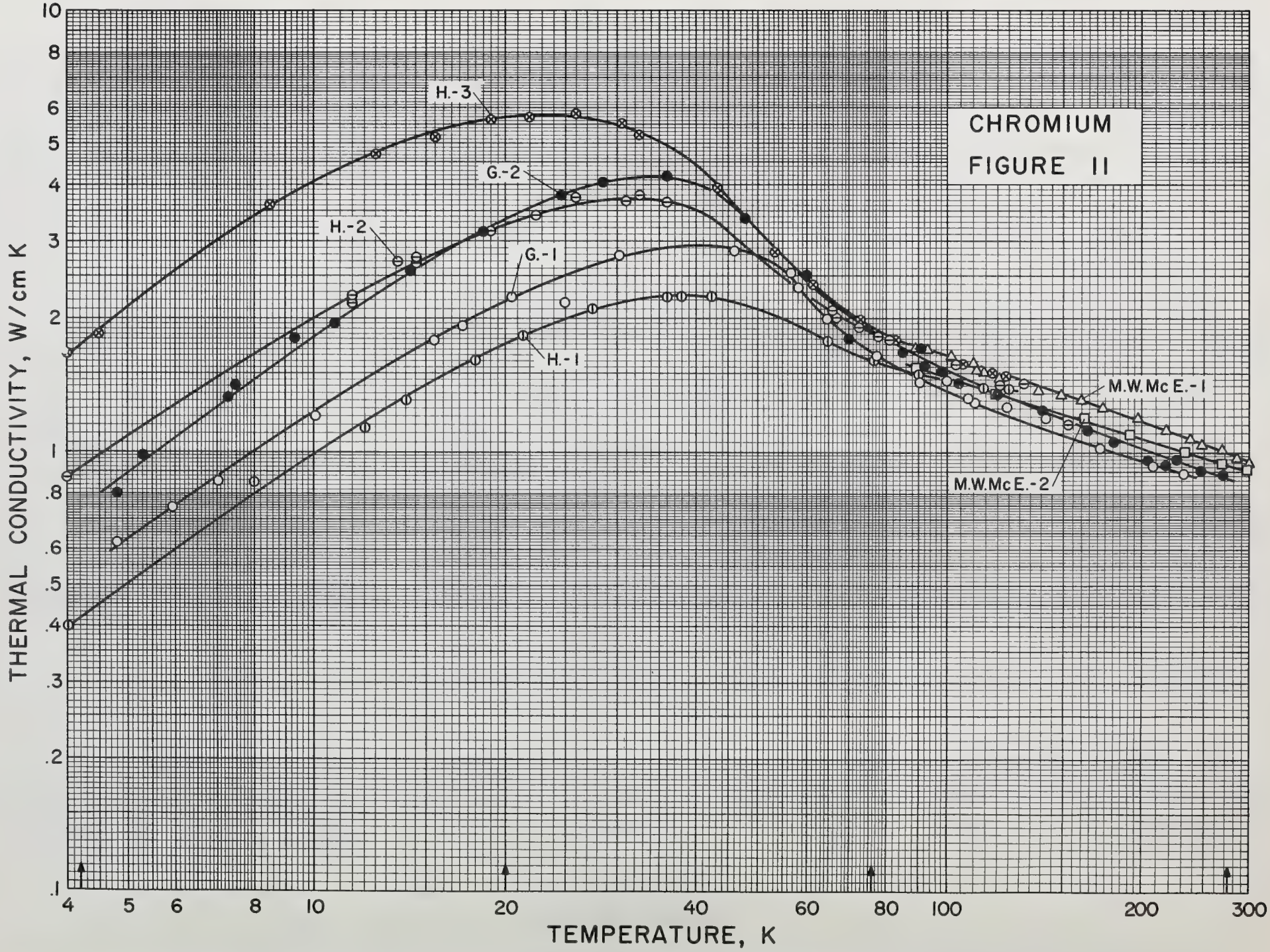
(See FIGURE 10)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	k = 544 mW/cm-K at 0°C. Specific density = 16.67.	A-5; B-5, C-1; D-2(2); E-2; F-5; G-3; S-1.	T. Barratt (1914).
. . . . .	. . . . .	k = 540 mW/cm-K at 17°C.	Same as above.	T. Barratt and R.M. Winter (1925).
. . . . .	Fansteel; 99.9% pure.	Aged for 2750 hrs. at 1800°C and 2000°C. k = 0.36 ± 0.04 at 0°C.	A-4; B-5; C-3; D-2; E-2; F-4; G-3; S-1.	M. Cox (1943).
. . . . .	. . . . .	Measured ratio of superconductive to normal thermal conductivity; $k_s/k_n < 1/60$ at 0.55 K.	. . . . .	C.V. Heer and J.G. Daunt (1949).
. . . . .	. . . . .	Graph of ratio of superconductive to normal thermal conductivity as a function of reduced temperature ranging from 0.35 to 1.	. . . . .	J.K. Hulm (1949).
M.O.-1, 1(s)	99.95% pure.	Apparatus described by J. L. Olsen (1952). Measured in both normal and superconducting (s) states.	G-2; N-2, 3.	K. Mendelssohn and J.L. Olsen (1950a).
H.-1, 1(s)	Hilger 8017; 0.1% (weight) impurities.	"Many small crystals"; impurities in solid solution. Measured both normal and superconducting (s) states. Graph of the lattice thermal conductivity as a function of temperature. Graph of the ratio of superconductive to normal thermal conductivity as a function of reduced temperature.	A-1; B-1; C-1; D-4(2); E-5; F-4; G-2; M-1; N-3; P-4; S-1.	J.K. Hulm (1950).
M.R.-1, 1(s)	Johnson, Matthey 3804; 99.98% pure.	Measured in both normal superconducting (s) states.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1; N-3; Q-1.	K. Mendelssohn and H.M. Rosenberg (1952b).
See FIGURE 70	Same as above.	Measured superconducting state below 1 K.	. . . . .	K. Mendelssohn and C.A. Renton (1953, 1955).

TANTALUM (cont'd)

(See FIGURE 10)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
R.	Same as above. RRR(20)= 19.7.	Continued M.R. curve to higher temperatures. T_c = 4.38K.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1,2; M-1; N-3; S-1,5.	H.M. Rosenberg (1955).
W.W.	Fansteel; 99.9% pure; RRR(22) = 62.	Annealed through self-heating by an electrical current at 2500°C in a vacuum. Graph of intrinsic thermal resistivity.	A-1; B-1; C-1; D-4(2); E-1,5; F-4; G-1; L-1,2; M-1; N-5; P-1; Q-1.	G.K. White and S.B. Woods (1959).
C.M.R.-1,1(s), 2,2(s)	#1: 0.005% Fe; 0.003% Si; 3 ppm O_2; 2.5 ppm H_2; RRR (20) = 63. #2: 0.1% Nb, 0.01% C, Fe, Mo, and W; 0.001% O_2; 7.5 ppm N_2; 4.5 ppm H_2; RRR(20)= 31.	#1: single crystal prepared by floating zone melting. Diamond pyramid hardness of 75. T_c = 4.32 ± 0.02K. #2: polycrystal. Both specimens measured in normal, intermediate, and superconducting (s) state. Graph of reduced thermal conductivity as a function of reduced temperature.	A-1; B-1; C-1; D-3(2); E-5,6; F-4; G-2; M-1; N-2,3; P-1,3.	A. Calverly, K. Mendelssohn, and P. M. Rowell (1961).
C.M.-1(s); See also FIGURE 70	Same as C.M.R.-1. RRR(20)= 47.	Prepared same as C.M.R.-1. Measured in the superconducting (s) state down to 0.2K. Graph of the ratio of superconductive to normal thermal conductivity as a function of reduced temperature. Graph of phonon mean-free-path as a function of reduced temperature.	A-1; B-1; C-1; D-3(2); E-5,6; F-4; G-2; M-2; N-3; P-4,5; Q-1.	A. Connolly and K. Mendelssohn (1962).
. . . . .	0.5% Nb; 0.06% Fe; 0.008% Ti; 0.005% W; 0.003% Si; 0.002% C; 0.001% Mo.	k = 450 mW/cm-K at 273K. Specimen was sintered from electrolytic powder in vacuum (10^{-3} Torr) for 5 hrs. at 1723K, and 5 hrs. at 2873K; refined twice by zone melting.	A-4; B-1; C-3; G-3.	N.Z. Pozdnyak and K.G. Akhmetzyanov (1963).
S.-1,1(s); also see FIGURE 70	Murex; 99.994% pure; RRR(20)= 80.	Single crystal; prepared by zone refining technique. Measured in both the normal (in magnetic field of 0.15T) and superconducting (s) states. Graph of ratio of superconducting to normal thermal conductivity as a function of reduced temperature. Graph of lattice conductivity in the normal and superconducting states. Also measured the normal and superconducting states below 1 K.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-3; O-5; P-5; Q-1.	J.K.N. Sharma (1967a and 1967b).


CHROMIUM
FIGURE 11
H.-3
G.-2
H.-2
G.-1
H.-1
M.W.McE.-1
M.W.McE.-2
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
10
8
6
5
4
3
2
1
.8
.6
.5
.4
.3
.2
.1
4
5
6
8
10
20
40
60
80
100
200
300

CHROMIUM

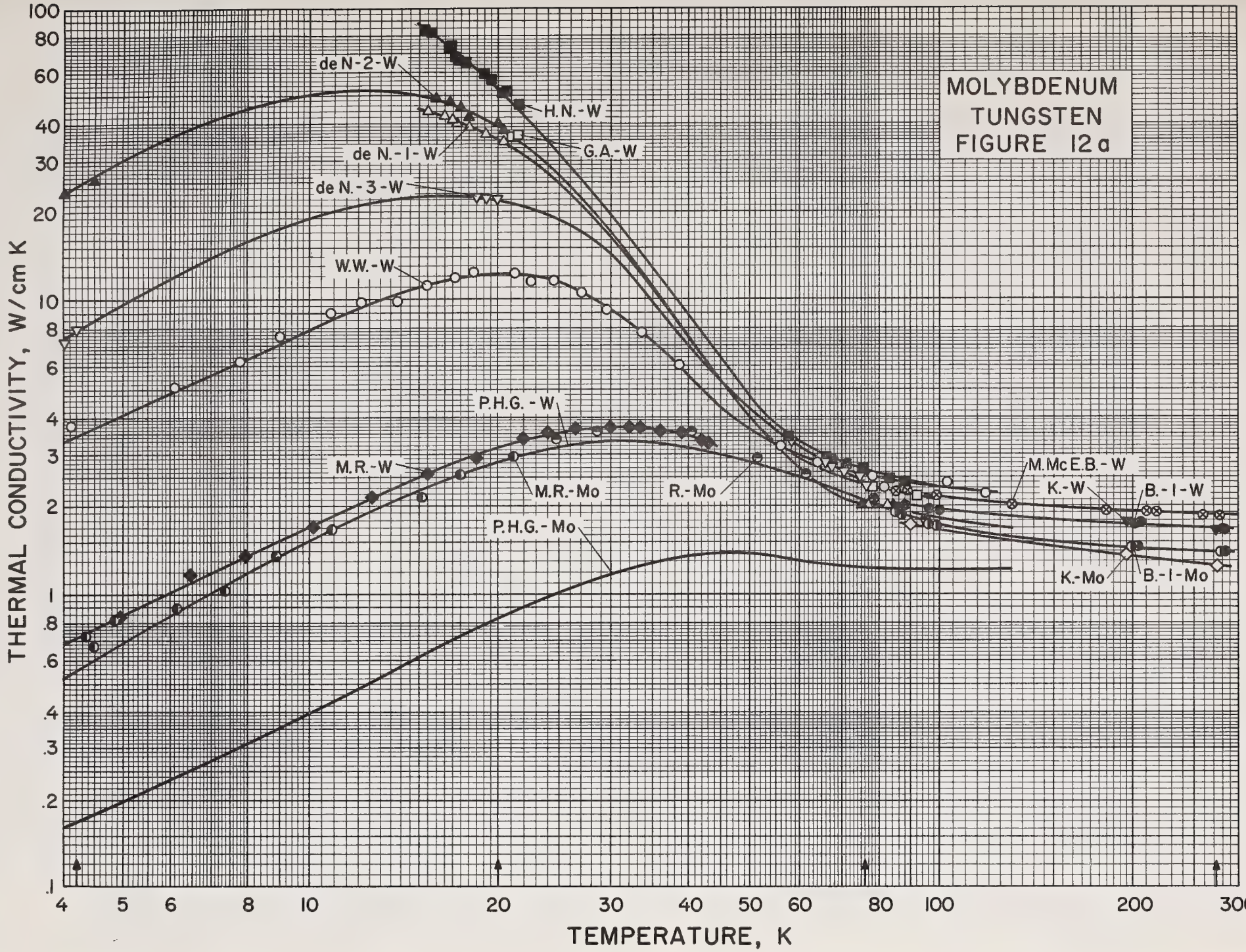
(See FIGURE 11)

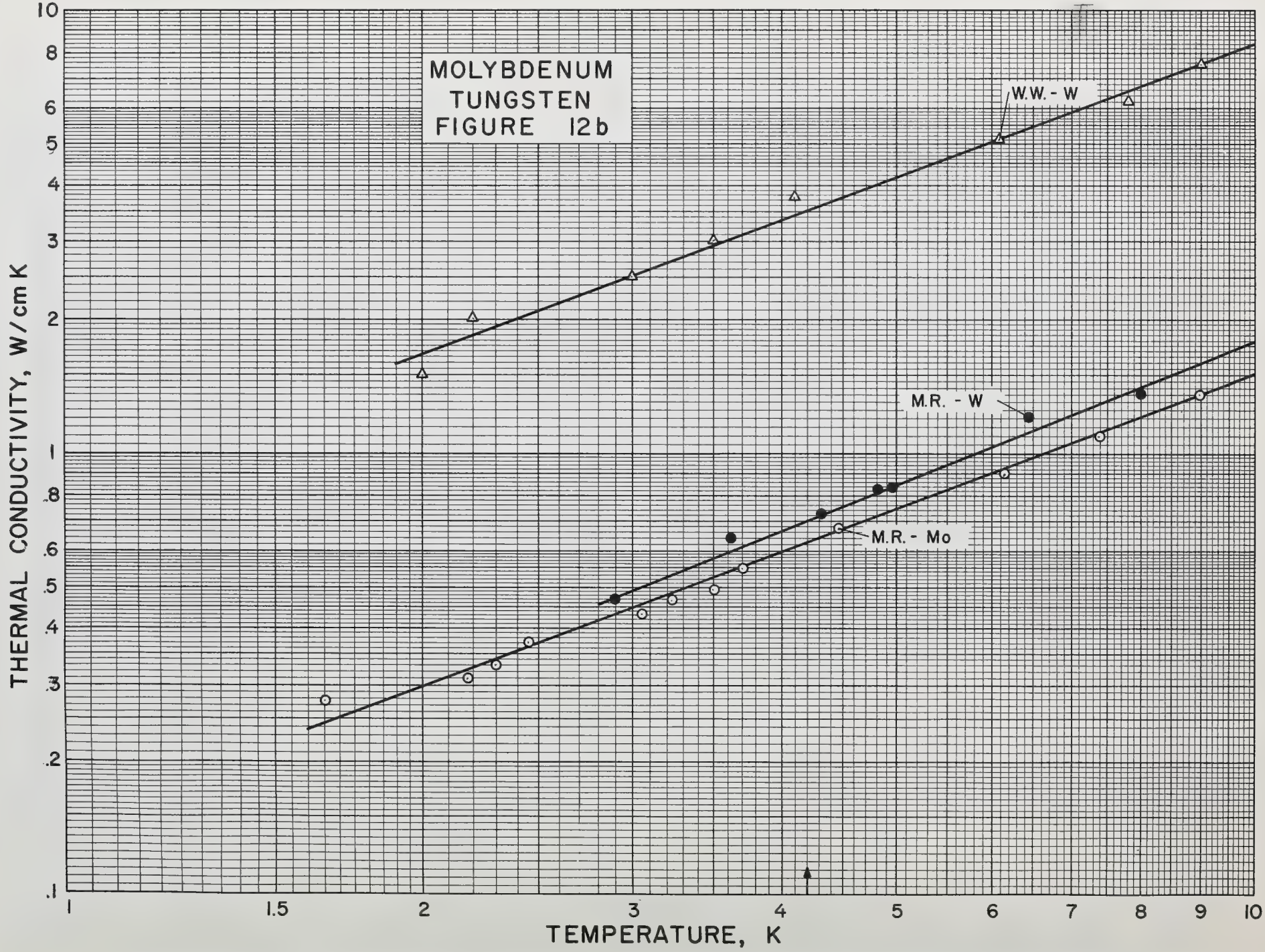
CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	Heraeus. RRR = 53.	k = 0.292 at 0°C. Electrolytically prepared.	A-1; B-1; C-1; D-1(2); E-2; F-4; G-3; S-1, 2, 4, 5.	H. Sochtig (1940).
H.-1, 2, 3	Aeronautical Research Laboratories, (Australia);~ 99.998% pure. #1: RRR = 47. #2: RRR = 96. #3: RRR = 218.	Forged, ground, and electropolished to size. #1: cold worked, ductile. #2: partially recrystallized. #3: fully recrystallized. Specimens #1 and #2 were later annealed and remeasured; the resulting thermal conductivity was between H.-1 and H.-2, and between H.-2 and H.-3, respectively. Graph of intrinsic thermal resistivity.	A-1; B-1; C-1, 2; D-4(2); E-2, 5; F-4; G-2; L-1, 2; M-1; N-5, 6; S-1, 5.	A. F. A. Harper, W. R. G. Kemp, P. G. Klemens, R. J. Tainsh, and G. K. White (1957).
M. W. McE.-1, 2	Chromalloy Corp.; > 99.98% pure. #1: 70 ppm C; 30 ppm Fe; < 20 ppm Ga and Mg; 14 ppm O_2; 10 ppm Mn; < 10 ppm Pt; 6 ppm Ca; 5 ppm H_2 and Si; 3 ppm B, N_2 and V; 2 ppm Ba, Cu, and Pb; < 2 ppm Zn; 1 ppm Ag and As; < 1 ppm of 13 others; RRR = 280. #2: 60 ppm C; 28 ppm N_2; < 20 ppm Ga; 9 ppm H_2; 8 ppm Mo; 6 ppm O_2; 5 ppm Cu, Ni, S, and Si; 4 ppm K; 3 ppm Co, Fe, and V; < 3 ppm Pt; < 2 ppm Sr and Zn; 1 ppm B; < 1 ppm of 17 others; RRR = 58.	#1: prepared by compacting iodide chromium crystals, sealing in an evacuated jacket, and hot extruding the assembly. Diamond pyramid hardness of 121 (longitudinal) and 120 (transverse); average grain diameter 63μ (transverse); density of 7.19 g/cm^3. #2: prepared by inert gas tungsten electrode arc melting of iodide chromium crystals. Diamond pyramid hardness of 123 (transverse, top and bottom); average grain size 840μ (transverse, top) and 440μ (transverse, bottom); density of 7.15 g/cm^3. Table of smoothed values of the thermal conductivity.	A-1; B-1; C-1; D-1(2); E-2; F-1; G-2; L-1, 2; M-1; N-5, 6; P-1; S-1, 2, 5.	J. P. Moore, R. K. Williams, and D. L. McElroy (1968).
. . . . .	. . . . .	Preliminary results; corrected results are found in J. F. Goff (1970) below.	. . . . .	J. F. Goff (1968).

CHROMIUM (cont'd)

(See FIGURE 11)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	A remeasurement of the specimen of J. F. Goff (1968) above 100 K. Results fell slightly below previous curve M. W. McE. -2.	. . . . .	J. P. Moore, R. K. Williams, and D. L. McElroy (1969).
G. -1, 2	99.92% (weight) pure; 0.005% Fe; 0.004% Mn; 0.003% Cu; 0.002% Mg; traces of Ni, P, S (weight). #1: RRR(24)= 72. #2: RRR(24)= 88.	Electrolytic chromium was cast in oxygen-free Cu boat by melting in an argon arc. #1: annealed in vacuum at 900°C for 24 hrs. #2: reannealed in vacuum at 900°C for 24 hrs. Graph of intrinsic thermal resistivity.	A-1; B-1; C-1; D-1(2), D-3 (2); E-2, 4, 5; F-1; G-2; L-1, 2; M-1; N-5, 6, 7; P-1; S-1, 2, 5.	J. F. Goff (to be published, 1970).


MOLYBDENUM
TUNGSTEN
FIGURE 12a
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
de N-2-W
H.N.-W
de N.-1-W
G.A.-W
de N.-3-W
W.W.-W
P.H.G.-W
M.R.-W
M.R.-Mo
R.-Mo
P.H.G.-Mo
M.McE.B.-W
K.-W
B.-1-W
K.-Mo
B.-1-Mo
100
80
60
40
30
20
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
4
5
6
8
10
20
30
40
50
60
80
100
200
300


MOLYBDENUM
TUNGSTEN
FIGURE 12b
W.W. - W
M.R. - W
M.R. - Mo
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
10
8
6
5
4
3
2
1
.8
.6
.5
.4
.3
.2
.1
1
1.5
2
3
4
5
6
7
8
9
10

MOLYBDENUM

(See FIGURES 12a and 12b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	k = 1.45 at 17°C. Specific density = 9.993.	A-5; B-5; C-1; D-2(2); E-2; F-5; G-3; S-1.	T. Barratt (1914).
. . . . .	. . . . .	Do.	Same as above.	T. Barratt and M. Winter (1925).
. . . . .	Philips; "very pure"; General Electric.	One specimen annealed at 900°C; k = 1.44 at 0°C. Another specimen annealed at 220°C; k = 1.32 at 0°C.	A-4; B-5; C-3; E-8; F-5; G-3; S-1, 5.	W. G. Kannuluik (1931).
K.-Mo	0.05% Bi and Cd; 0.01% Aℓ, Ge, Sn, Ti, V, and W; 0.001% Co, Cu, Pt, and Rh; trace of C.	. . . . .	A-4; B-5; C-3; E-8; F-5; G-3; L-1; S-1, 5.	W. G. Kannuluik (1933).
M.R.-Mo	Johnson, Matthey 2331; 99.95% pure.	. . . . .	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1.	K. Mendelssohn and H. M. Rosenberg (1952b).
R.-Mo	Same as above. RRR(20) = 36.2.	Unannealed. Continuation of the M.R.-Mo curve to higher temperatures.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1; S-1, 5.	H.M. Rosenberg (1955).
P.H.G.-Mo	Los Alamos Scientific Laboratory; 1-2% (by volume) ThO_2; 0.01 - 0.1% Fe, and Si; 0.001 - 0.01% Aℓ, Cu, and Nb; < 0.001% Ca, Cr, and Mg (mole percentages).	Molybdenum doped with ThO_2. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-1(8); E-2, 5; F-2; G-2; L-1, 2; M-1, 4; P-2, 3; Q-1; S-1, 2, 5.	R.L. Powell, J.L. Harden, and E.F. Gibson (1960).
B.-Mo	Johnson, Matthey; "spectroscopically standardized material".	Graph of lattice thermal resistivity.	A-1; B-1; C-1; D-1(2); F-2; G-2; L-1; M-1; N-5; O-3; P-1; Q-1; S-1, 5.	N.G. Bäcklund (1967).

TUNGSTEN

(See FIGURES 12a and 12b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	Isenthal and Co.	k = 2.0 at 17°C.	A-5; B-5; C-1; D-2(2); E-2; F-5; G-3; S-1.	T. Barratt (1914).
. . . . .	Philips.	Annealed at 225°C for 20 hrs. k = 1.6 at 0°C.	A-4; B-5; C-3; E-8; F-5; G-3; S-1, 5.	S. Weber (1917).
. . . . .	Same as T. Barratt (1914) above.	Same as T. Barratt (1914) above.	Same as T. Barratt (1914) above.	T. Barratt and R. M. Winter (1925).
. . . . .	Philips; "very pure"; RRR=830.	Single crystal; deposited from the gas phase; k = 34.3 at 21.2K; k = 2.32 at 83.2K. Also, an impure single crystal from Osram gave values of 1.80 at 21.2K and 1.83 at 83.2K.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-3; L-1, 2; M-1; P-1; S-1, 5.	E. Grüneissen and E. Goens (1927).
. . . . .	General Electric; "relatively impure".	One specimen annealed at 220°C; k = 1.64 at 18°C. Another specimen annealed at 1300°C, k = 1.66 at 18°C.	A-4; B-5; C-3; E-8; F-5; G-3; S-1, 5.	W. G. Kannuluik (1931).
K.-W	Philips; 0.01% Si, Ta, and V; 0.001% Co, Cr, In, Os, Pt, and Sn; trace of Se; RRR (273K/90K) = 5.9.	Single crystal wire; hexagonal cross section; axis of wire in (111) plane. Another wire of rectangular cross section, with axis in (100) plane had values 10% lower at 90K.	A-4; B-5; C-3; E-8; F-5; G-3; L-1; S-1, 5.	W. G. Kannuluik (1933).
. . . . .	Philips; RRR = 2200 (see Remarks).	Values ranging from k = 23.8 at 15.5K to k = 18.2 at 21.8K. Graph of intrinsic thermal resistivity. Correspondence from the authors to Grüneisen and Adenstedt (1937) indicated that the values should be considerably raised, e.g. k = 51.3 at 20.5K with RRR = 2800.	A-1; B-1; C-1; D-2(2); E-2; F-4; G-3; L-1, 2; M-1; S-1, 5.	H. Bremmer and W. J. de Haas (1936 a).
. . . . .	General Electric.	Annealed at 2000, 2400, and 2800K. k = 1.66 at 0°C.	A-4; B-5; C-3.	I. Langmuir and J. B. Taylor (1936).
. . . . .	. . . . .	At 78, 194, and 273K, the results are approximately 5-10% higher than Kannuluik (1933).	. . . . .	W. C. Michels and M. Cox (1936).

TUNGSTEN (cont'd)

(See FIGURES 12a and 12b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
G.A.-W	Same stock as E. Grüneisen and E. Goens (1927) above.	Specimen prepared by van Arkel process. Specimen axis 9° from [110] direction toward [111] direction. Graphs of: a) the anisotropy of the thermal conductivity as a function of the direction of the magnetic field; and b) the thermal conductivity as a function of transverse magnetic field up to 0.67 T.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-3; L-1; M-1; N-2, 4; P-1; S-1, 2.	E. Grüneisen and H. Adenstedt (1937).
H.N.-W	Same as B.H.-W above.	Single crystal; hexagonal cross section; axis of the rod presumed parallel to the [111] direction. Graph of reduced thermal resistivity as a function of temperature and field up to 2.58 T.	A-1; B-1; C-1; D-2(2); E-2, 5; F-4; G-2; L-1; M-1; P-1; S-1, 5.	W.J. de Haas and J. de Nobel (1938).
. . . . .	Same specimen as G.A.-W above; RRR = 590.	Single crystals prepared by the van Arkel process; results in 0 magnetic field the same as G.A.-W; for another crystal with rod axis parallel to [100] axis, k = 22.1 at 21 K. Graph of thermal resistivity as a function of transverse magnetic field up to 1.2 T.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-3; L-1; M-1; N-2, 4; P-1; S-1, 5.	E. Grüneisen and H. Adenstedt (1938).
. . . . .	General Electric.	Drawn wire; aged for 370 hrs. at 2300°C. k = 1.93 at 77 K; k = 1.87 at 90 K; k = 1.69 at 0°C.	A-4; B-5; C-3; D-2; E-2; F-4; G-3; S-1, 5.	M. Cox (1943).
. . . . .	Same as H.N.-W above.	Extended the measurements of W.J. de Haas and J. de Nobel (1938) up to 3.6 T.	. . . . .	J. de Nobel (1949).
M.R.-W	Johnson, Matthey 2260; 99.99% pure.	Annealed in vacuum at 1150°C for several hours.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1.	K. Mendelssohn and H. M. Rosenberg (1952b).
. . . . .	Same as M.R.-W above. RRR(20) = 38.	Annealed in vacuum at 1150°C for several hours. Review of previous paper.	. . . . .	H.M. Rosenberg (1955).

TUNGSTEN (cont'd)

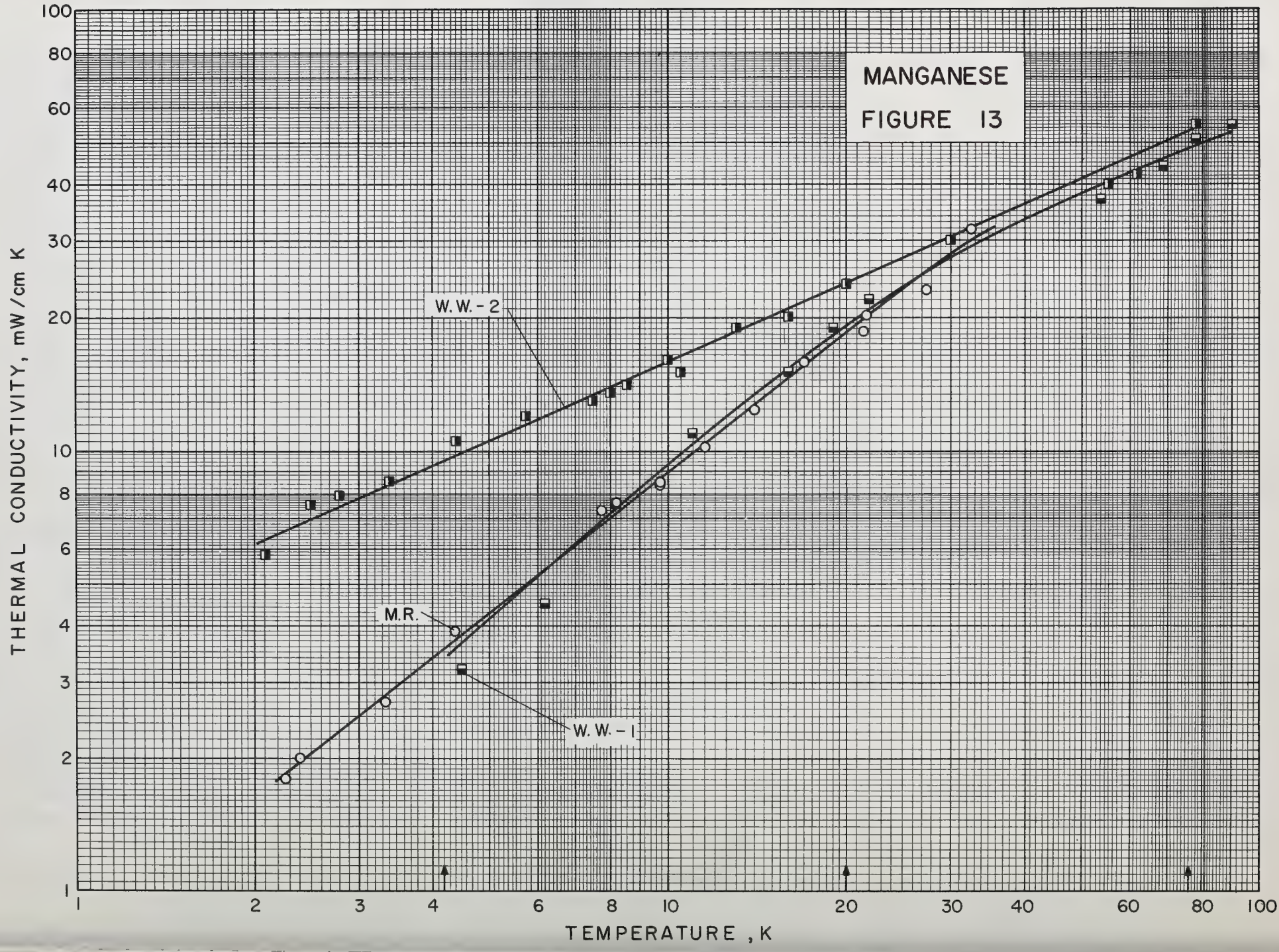
(See FIGURES 12a and 12b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
W.W.-W	Johnson, Matthey 3610; ~0.01% Mo; faint spectral lines of Cu, Fe, and Si; RRR(22) = 170.	Annealed in vacuum at 1350°C for some hours, kept at 600°C for some hours, then cooled. Graph of intrinsic thermal resistivity.	A-1; B-1; C-1; D-4(2); E-1,5; F-4; G-1; L-1,2; N-5; S-1.	G.K. White and S.B. Woods (1957c).
deN.-1,2,3-W	#3: RRR = 385.	#1: hexagonal cross section, diameter < 1 mm; rod axis roughly [111] direction. #2: square cross section, diameter < 1 mm; rod axis roughly parallel to [100] direction. #3: rod axis within 5° of the [100] direction. Graphs and tables of thermal conductivity as a function of magnetic field up to 3.26 T. Graph of thermal conductivity as a function of magnetic field orientation.	A-1; B-1; C-1; D-2(2); E-2,5; F-4; G-2; L-1,2; M-1; N-2,4,8; P-1; S-1.	J. de Nobel (1957).
P.H.G.-W	Los Alamos Scientific Laboratory; 1-2% (by volume) ThO_2; 0.01-0.1% Si; 0.001-0.01% Nb and Fe; < 0.001% Al, Cr, Cu, Mg, Mn, and Mo (mole percentages).	Tungsten doped with ThO_2. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-1(8); E-2,5; F-2; G-2; L-1,2; M-1,4; P-3; Q-1; S-1,2,5.	R.L. Powell, J.L. Harden, and E.F. Gibson (1960).
M.McE.B.-W	"High purity"; RRR > 400. Another specimen was 99.98% pure; RRR = 31.4.	Electron-beam melted. Density of 19.29 g/cm^3. The other specimen had density of 19.077 g/cm^3; the thermal conductivity curve of this other specimen was quite similar in shape but 10% lower than that for the high purity.	A-1; B-1; C-1; D-1(2); E-1; F-1; G-1; L-1,2; S-1,2,5.	J.P. Moore, D.L. Mc Elroy, and M. Barisoni (1966).
B.-W	Johnson, Matthey; "spectroscopically standardized material".	Graph of lattice thermal resistivity.	A-1; B-1; C-1; D-1(2); F-2; G-2; L-1; M-1; N-5; O-3; P-1; Q-1; S-1,5.	N.G. Bäcklund (1967).
See FIGURE 69	. . . . .	Measured below 1 K.	. . . . .	J.K.N. Sharma (1967 a).
. . . . .	. . . . .	Graphs of electrical resistivity and intrinsic thermal resistivity of nine single crystals between 1.5 and 6.0 K.	. . . . .	D.K. Wagner, J.C. Garland, and R. Bowers (1971).

TUNGSTEN (cont'd)

(See FIGURES 12a and 12b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	Graph of thermal resistivity tensors for a single-crystal tungsten specimen between 1.4 and 4.1 K and in magnetic fields up to 2.2 Tesla.	. . . . .	J. R. Long (1971).


MANGANESE
FIGURE 13
THERMAL CONDUCTIVITY, mW/cm K
TEMPERATURE , K
W. W. - 2
M.R.
W. W. - 1
100
80
60
40
30
20
10
8
6
4
3
2
1
1
2
3
4
6
8
10
20
30
40
60
80
100

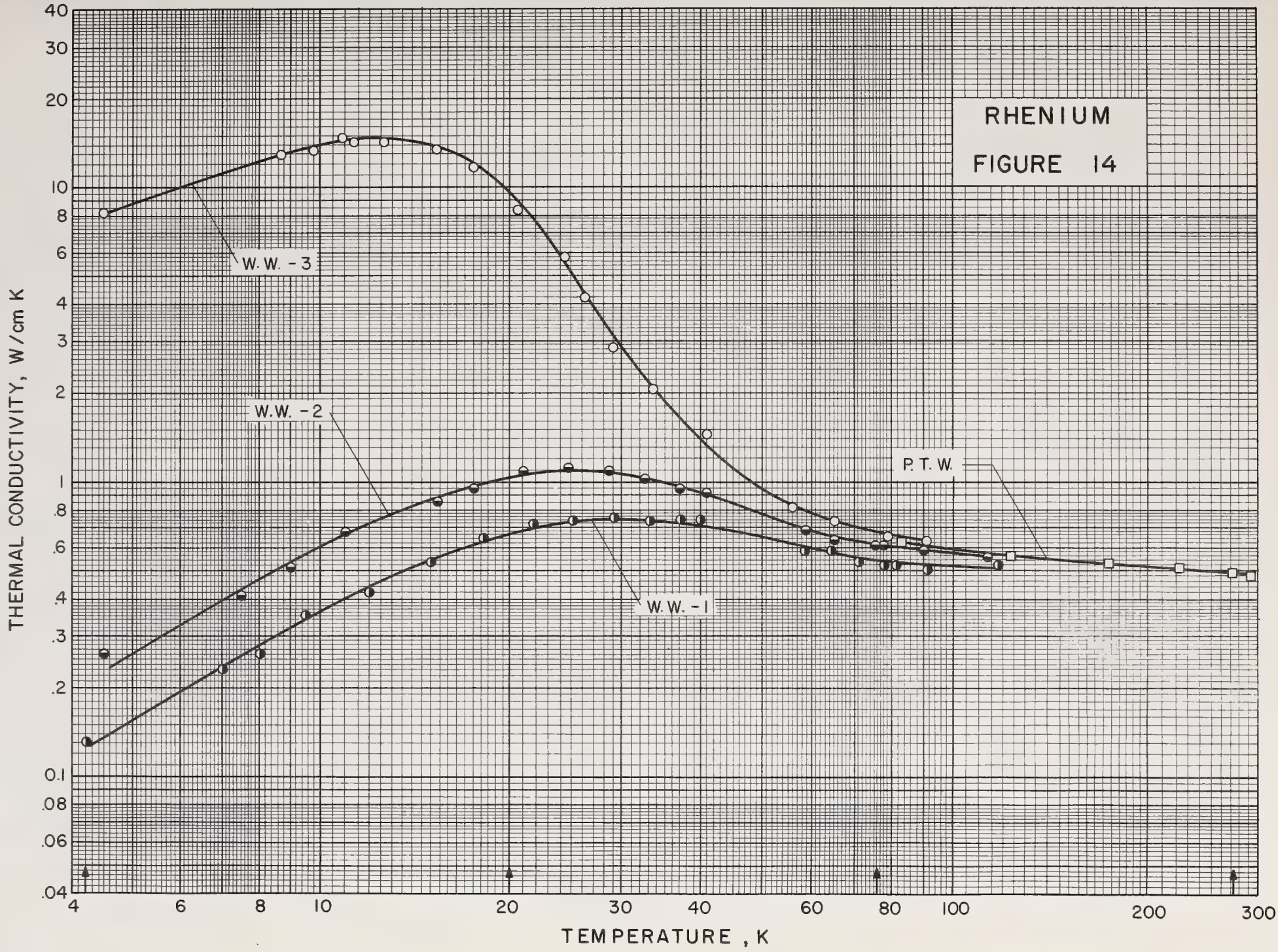
MANGANESE

(See FIGURE 13)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	Interpolated value of k = 50 mW/cm-K at 83 K for the β phase.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-3.	H. Reddemann (1935).
M.R.	Johnson, Matthey 2472; 99.99% pure.	α-manganese, annealed in vacuum for several hours.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; M-1.	K. Mendelssohn and H. M. Rosenberg (1952 b).
. . . . .	Same as above. RRR(20) = 1.47.	Electrolytic. Review of previous paper.	. . . . .	H. M. Rosenberg (1955).
W.W.-1,2	Johnson, Matthey 10792; "high purity"; 10 ppm Mg.	#1: annealed in vacuum at 600°C. #2: as received.	A-1; B-3; C-1; D-4(2); E-1,5; F-4; G-1; L-1; M-1; S-1.	G.K. White and S.B. Woods (1957 b).
. . . . .	Same as above. 99.99% pure. Specimen W.W.-1: RRR(22) = 14. Specimen W.W.-2: RRR(22) = 1.1.	Review of previous paper.	. . . . .	G.K. White and S.B. Woods (1959).
. . . . .	Johnson, Matthey 810; Ca and Mg impurities; < 0.01% S; some gaseous impurity.	Electrolytically prepared α-Mn flakes. k = 78 mW/cm-K at 20°C.	A-6; B-3; D-1(2); F-5; G-3.	B.W. Jolliffe, R. P. Tye, and R. W. Powell (1966).

TECHNETIUM

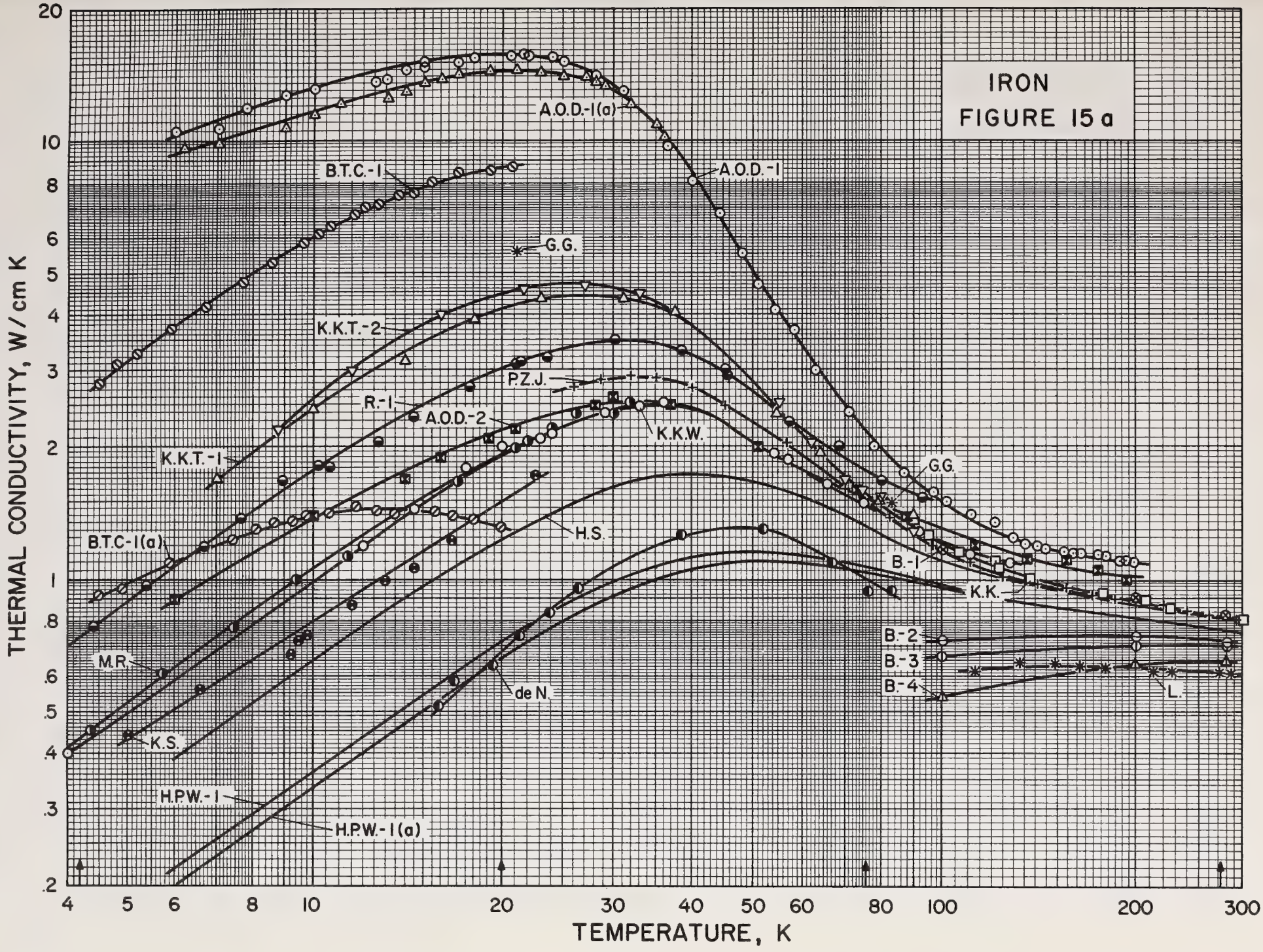
CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	150 ppm total metallic impurities (principally Aℓ and Fe); 3 ppm N_2; 2 ppm O_2 (after melting).	Reduced from ammonium-pertechnetate in an hydrogen furnace; electron beam method; diamond pyramid hardness of 108 to 134 (120 average). Lattice parameters: a_o = 2.7414Å, c_o = 4.3997Å. k = 0.494, calculated from thermal diffusivity measurements; estimated average inaccuracy of about 10%.	. . . . .	D.E. Baker (1965).

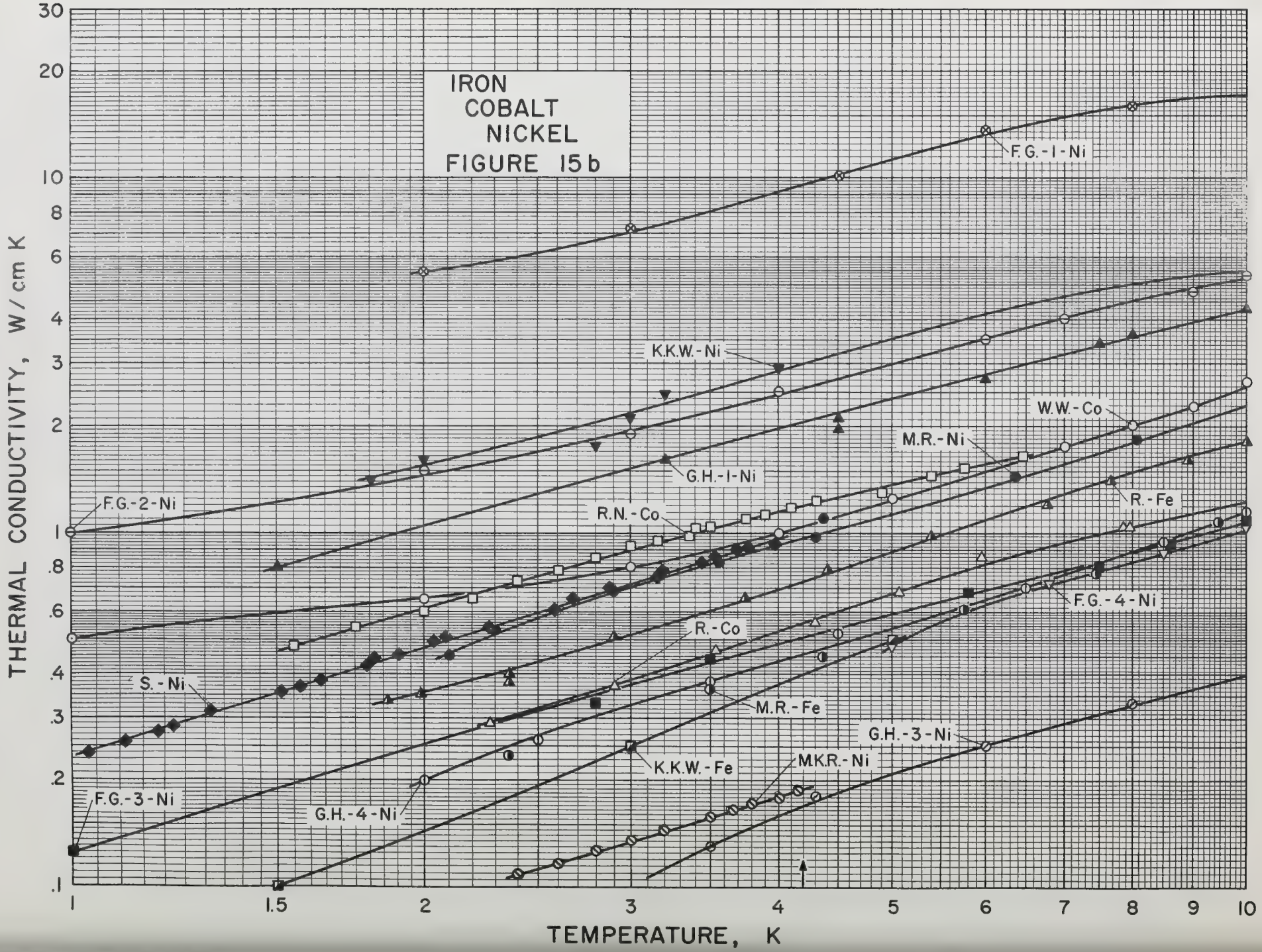

RHENIUM
FIGURE 14
W. W. - 3
W.W. - 2
W.W. - 1
P. T. W.
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE , K
40
30
20
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
0.1
.08
.06
.04
4
6
8
10
20
30
40
60
80
100
200
300

RHENIUM

(See FIGURE 14)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
W.W.-1, 2, 3	#1: A.D. McKay; > 99.5% pure; < 0.1% total metallic impurity; spectral lines of Cu, Fe, and Mo; RRR(22) = 25. #2: same as #1; RRR (22) = 41. #3: Institute of Metals (Chicago University); "very pure"; < 0.01% total impurity content; RRR(22) = 1360.	#1: specific density of 21.3 at room temperature. #2: annealed in vacuum for 2 hrs. at 700°C; specific density same as #1. #3: prepared by zone melting compressed rhenium powder in an argon arc furnace. Graph of intrinsic thermal resistivity.	A-1; B-1; C-1; D-4(2); E-1, 5; F-4; G-1; L-1, 2; N-5; S-1.	G.K. White and S. B. Woods (1957c).
P.T.W.	Johnson, Matthey; "high purity"; traces of the noble metals; RRR = 220.	Density of 20.98 g/mol.	A-1; B-1; C-1; D-1(2); F-4; G-2; L-1; P-1; S-1, 5.	R.W. Powell, R.P. Tye, and M.J. Woodman (1963).
See FIGURE 69	. . . . .	Measured both normal and superconducting states below 1 K.	. . . . .	J.K.N. Sharma (1967 a and 1967 b).


IRON
FIGURE 15 a
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
A.O.D.-1(a)
A.O.D.-1
B.T.C.-1
G.G.
K.K.T.-2
P.Z.J.
R.-1
A.O.D.-2
K.K.W.
K.K.T.-1
G.G.
H.S.
B.T.C.-1(a)
B.-1
K.K.
B.-2
B.-3
B.-4
L.
M.R.
de N.
K.S.
H.P.W.-1
H.P.W.-1(a)
20
10
8
6
5
4
3
2
1
.8
.6
.5
.4
.3
.2
4
5
6
8
10
20
30
40
50
60
80
100
200
300


IRON
COBALT
NICKEL
FIGURE 15b
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
30
20
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
1
1.5
2
3
4
5
6
7
8
9
10
F.G.-1-Ni
K.K.W.-Ni
W.W.-Co
M.R.-Ni
G.H.-1-Ni
F.G.-2-Ni
R.N.-Co
R.-Fe
F.G.-4-Ni
R.-Co
S.-Ni
M.R.-Fe
G.H.-3-Ni
K.K.W.-Fe
M.K.R.-Ni
F.G.-3-Ni
G.H.-4-Ni

IRON
(See FIGURES 15a and 15b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	"Pure".	k = 0.70 at 0°C.	A-5; B-1; C-1; D-7(9); F-5; G-3; S-1, 3.	L. Lorenz (1881 a).
. . . . .	Krupp; "pure"; 0.1% C; 0.06% Mn; 0.05% Cu; 0.03% P; 0.015% S and Si.	k = 0.72 at 18°C. Specific density of 7.87.	A-1; B-1; C-2; D-1(2); F-5; G-3; S-1, 3, 5.	E. Grüneisen (1900).
. . . . .	0.1% C and metals.	k = 0.67 at 18°C.	. . . . .	W. Jaeger and H. Diesselhorst (1900).
. . . . .	Krupp; 0.2% Si; 0.1% C and Mn.	k = 0.60 at 18°C.	. . . . .	Same as above.
L.	99.42% pure; 0.15% Mn; 0.13% Si; 0.1% C.	Wrought iron; turned from a bar of best scrap; specific density of 7.74 at 21°C.	A-1; B-1; C-1; D-2(2); E-2; F-4; G-3; L-1; S-1, 5.	C.H. Lees (1908).
. . . . .	. . . . .	Electrolytic; two rods with average grain diameter of 1×10^{-1} and 6×10^{-3}cm; k = 0.94 and k = 0.90, respectively, at 0°C; k = 1.84 and k = 1.83, respectively, at 80 K.	A-1; B-1; C-1; D-1(2); F-4; G-3; P-1; S-1, 5.	A. Eucken and K. Dittrich (1927).
. . . . .	Heraeus.	Electrolytic; average grain diameter of 1.6×10^{-3}cm; k = 0.82 at 0°C; k = 1.17 at 80 K.	Same as above.	Same as above.
G. G. (2 points only)	"Double refined"; RRR = 128.	Worked and then tempered; electrolytic.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-3; L-1, 2; M-1; P-1; S-1, 5.	E. Grüneisen and E. Goens (1927).
. . . . .	#2: "technically pure"; RRR = 63. #3: RRR = 9.4.	#2: untempered; electrolytic; k = 1.36 at 83 K; k = 3.01 at 21 K. #3: heavily worked; electrolytic; k = 0.91 at 83 K; k = 0.49 at 21 K.	Same as above.	Same as above.
. . . . .	"Pure".	Electrolytic; k = 0.77 at 16°C.	A-4; B-1; C-3; D-1(2); F-4; G-3; S-1, 5.	R. Kikuchi (1932).
. . . . .	Armco; 0.06% Ca; 0.056% Cu; 0.026% S; 0.017% Mn; 0.011% C; 0.006% P; 0.002% Si.	k = 0.71 at 0°C; k = 0.72 at 195 K; k = 0.94 at 90 K.	A-4; B-5; C-3; E-8; F-5; G-3; L-1; S-1, 5.	W. G. Kannuluik (1933).

IRON (cont'd)
(See FIGURES 15a and 15b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	National Physical Laboratory (Teddington).	Reduced from ferrous chloride and then oxide; hydrogen treated at 800°C; sintered at 1050°C; then vacuum melted in alumina crucible by an induction furnace; k = 0.79 at 25°C (measurements by R.W. Powell).	A-1; B-1; C-1, 2; D-1(2); F-3; G-2; S-1, 5.	F. Adcock and C.A. Bristow (1935).
K.S.	"Pure". RRR = 29.	Electrolytic.	A-1; B-1; C-1; D-1(2); E-4, 5; F-4; G-3; M-1; S-1, 5.	J. Karweil and K. Schäfer (1939).
deN.	Hadfield; 99.93% pure.	Forged; Brinell hardness of 103. k = 0.9 at 90K; maximum of k = 1.3 at 52K; k = 0.5 at 15K.	A-1; B-1; C-1; D-4(1); E-5; F-4; G-2; L-1; M-1.	J. de Nobel (1951).
P.Z.J.	Johnson, Matthey; 99.99% pure.	. . . . .	A-1; B-1; C-1; D-1(2); E-1; F-2; G-2; L-1, 2; M-1.	R.W. Powers, J.B. Ziegler, and H.L. Johnston (1951 a).
M.R. (FIG. 15 a), M.R.-Fe (FIG. 15b)	Johnson, Matthey 4975; 99.99% pure; RRR(20) = 44.6.	Annealed in vacuum for several hours.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1.	K. Mendelssohn and H.M. Rosenberg (1952b).
R. (FIG. 15 a), R.-Fe (FIG. 15b)	Same as above. 0.21% O_2; 0.01% C; N_2 and H_2 not detected; RRR(20) = 67.8.	Review of M.R. results; remeasurement of M.R. specimen. Higher conductivity probably caused by age-hardening, precipitation of impurities, especially O_2 or C.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1, 2; N-8.	H.M. Rosenberg (1955).
K.K.W. (FIG. 15 a), K.K.W.-Fe(FIG. 15b)	Johnson, Matthey 5092; 99.99% nominal purity; 50 ppm Ni; 2 ppm C; 1 ppm Ag; Mg and Mn spectral lines barely visible; RRR(22) = 41.	Annealed in vacuum for 4 hrs. at 750°C. Graph of intrinsic thermal resistivity.	A-1; B-1; C-1; D-4(2); E-2, 5; F-4; G-2; L-1, 2; M-1; N-5; S-1, 5.	W.R.G. Kemp, P.G. Klemens, and G.K. White (1956).
K.K.T.-1, 2	Same stock as G.G. #1: RRR = 104. #2: RRR = 89.	Doubly refined, electrolytic iron, not melted in vacuum but cut out of a precipitated plate; annealed at 950°C to remove H_2 then compressed to destroy the precipitation structure and reannealed in vacuum at 95°C. Graph of intrinsic thermal resistivity.	A-1; B-1; C-1; D-4(2); E-2, 5; F-4; G-2; L-1, 2; M-1; N-5; S-1, 5.	W.R.G. Kemp, P.G. Klemens, and R.J. Tainsh (1959 a).

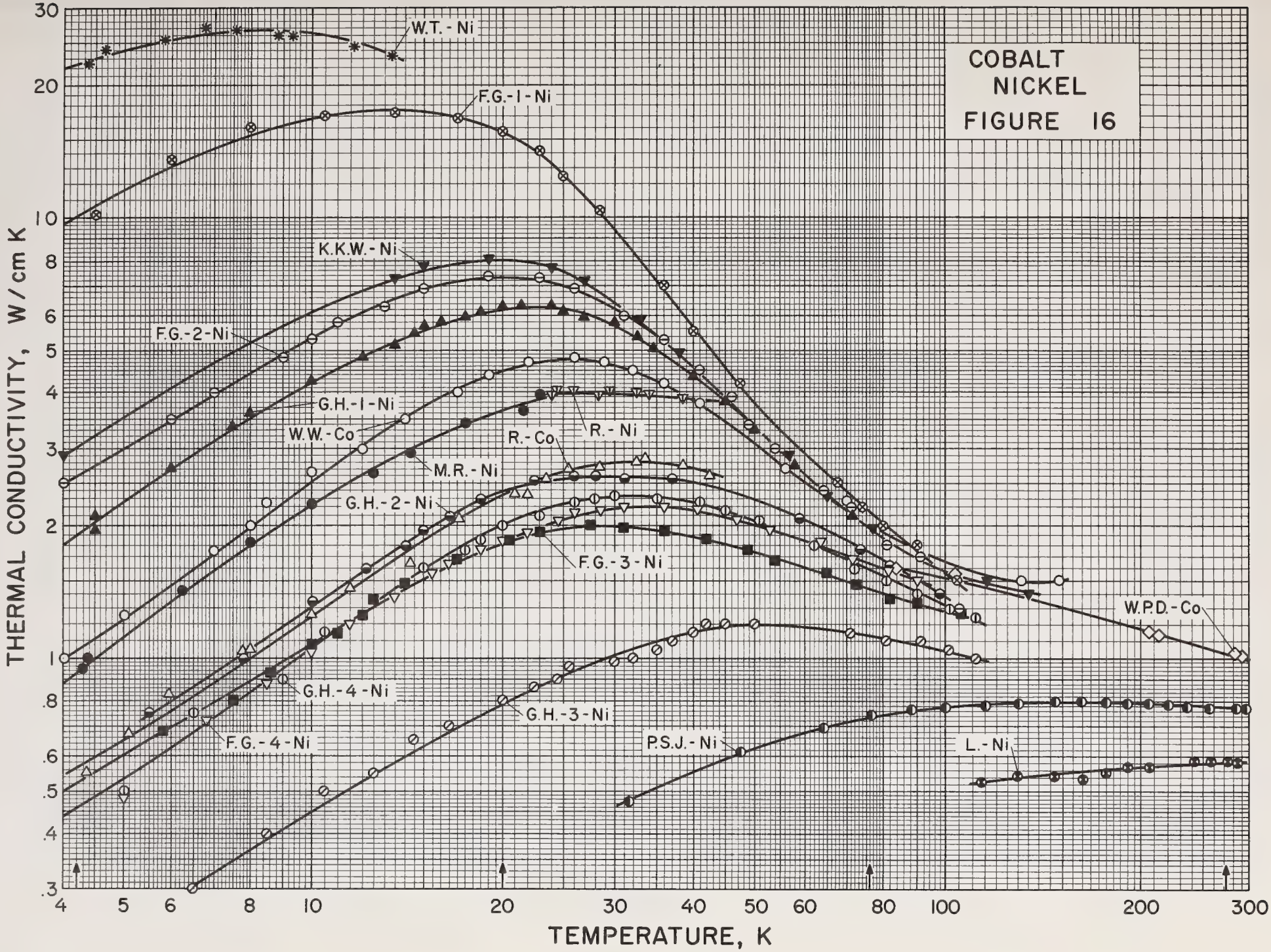
IRON (cont'd)

(See FIGURES 15a and 15b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
B.-1, 2, 3, 4	#1: Philips. #2: Heraeus; 0.26% Mn (solute may be attended with some impurity). #3: Heraeus; 0.90% Ni. #4: Heraeus; 0.53% Mn (solute may be attended with some impurity).	Annealed for 2 hrs. at 1100°C in evacuated silica tubes in order to remove segregation inhomogenities. #1: several pieces of the original wire were coupled in parallel to increase the effective cross section of the specimen. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-1(2); F-4; G-2; L-1, 2, 3; M-1; N-5; O-1; P-1, 3; Q-1, 5; S-1, 5.	N. G. Bäcklund (1961).
See FIGURE 69	. . . . .	Measured below 1 K.	. . . . .	G. Davey and K. Mendelssohn (1963).
A.O.D.-1, 1(a), 2	Bain Laboratory. #1: < 20 ppm O_2; < 6 ppm N_2; 4 ppm C; 1.5 ppm Co; 1.1 ppm Cu; 0.65 ppm Cr; 0.2 ppm Ti; 0.19 ppm Ge; 0.18 ppm V(by weight); RRR (24) = 302. #2: 230 ppm C; 140 ppm O_2; 116 ppm S; 100 ppm Si; 40 ppm P; 23 ppm Cu; 17 ppm Ti; 16 ppm Zr; 13 ppm Ge; 10 ppm Ni; 9 ppm Cr and Mg; 7 ppm Mn; 5 ppm As; 4 ppm Co; 3 ppm Ca; RRR(24)= 27.1.	#1: ferric chloride, prepared from commercial electrolytic iron; was distilled once, and then reduced with H_2; bulk metal was electron-beam drip melted into ingots, then zone melted; swaged with intermediate annealing treatments in hydrogen, a final anneal for $\frac{1}{2}$ hr. at 650°C, then chemically polished; the final equiaxed grain size was about 100μ. #2: vacuum melting of commercial electrolytic iron. Curve 1(a) was obtained after the completion of the run on specimen #1, during which the specimen warmed to room temperature. Slightly lower values of thermal conductivity for 1(a) are believed to have resulted mainly from structural imperfections produced by temperature cycling.	A-1; B-1; C-1; D-1(2); E-1; F-4; G-2; L-1, 2; M-1; N-6; P-1; R-2; S-1, 5.	S. Arajs, B.F. Oliver, and G.R. Dunmyre (1965).
K.K.	99.993% pure; 27 ppm C; 20 ppm S; 10 ppm Mn, N_2, and Si; trace of Cr.	Vacuum melted. Graph of electronic and lattice component of thermal conductivity.	A-1; B-1; C-1; D-1(3); F-4; G-2; L-1, 2; N-5; P-1; S-1, 5.	R. Kohlhaas and W. Kierspe (1965).
. . . . .	Materials Research Corp.; > 99.95% pure; RRR = 201.	Machined from electron-beam zone-refined iron; designated Grade 1. Density of 7.824 g/cm^3. Values are 5% greater at 80 K and within 2% at 300 K of the K. K. curve.	A-1; B-1; C-1; D-1(2); E-1; F-1; G-1; L-1, 2; S-1, 2, 5.	J.P. Moore, D.L. McElroy, and M. Barisoni (1966).

IRON (cont'd)
(See FIGURES 15a and 15b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
H.P.W.-1,2	Battelle Memorial Institute; 99.9% pure; 0.04% Cu; 0.028% Mn; 0.025% S; 0.015% C; 0.005% P; 0.003% Si. #1: RRR = 13.83. #2: RRR = 12.58.	Armco iron; annealed in gas-heated air muffle $\frac{1}{2}$ hr. at 870°C, then annealed in quartz capsule at 10^{-6} Torr for $1\frac{1}{2}$ hrs. at 875°C, furnace cooled to 150°C, held at that temperature for 24 hrs. then cooled to room temperature. Hardness, after machining: B-40.0; after reannealing with above procedure: B-37.1. Grain size: after machining, 0.053 mm; after reannealing, 0.064 mm.	A-1; B-1; C-1; D-1(8); E-1, 2, 3; F-1; G-1; L-1, 2; M-1; S-1, 2, 5.	J.G. Hust, R.L. Powell, and D. H. Weitzel (1970).
H.S.	National Bureau of Standards, Office of Standard Reference Materials; 0.037% Ni, 0.013% Si, 0.010% C, 0.008% Mn and S, 0.007% Co and Cr, 0.006% Cu and O_2, 0.005% Mo, 0.004% Ti, 0.003% As, 0.002% Aℓ and P, < 0.001% Ta, 10 ppm Ge and N_2, 2 ppm Zn, 1.5 ppm B, ~1 ppm H_2, 0.5 ppm Sb, 0.4 ppm Ca and Zr, 0.3 ppm Pb, < 0.2 ppm Mg, 0.1 ppm Bi, < 0.05 ppm Te, 0.02 ppm Ag and Ce, < 0.02 ppm Se, 0.01 ppm La, < 0.01 ppm Pr; RRR = 23.42.	OSRM iron - 1265; annealed 2 hrs at 1000°C.	A-1; B-1; C-1; D-1(8); E-1, 2, 3; F-1; G-1; L-1, 2; M-1; S-1, 2, 5.	J.G. Hust, and L.L. Sparks (to be published).
B.T.C.-1, 1(a)	. . . . .	#1: rod axis parallel to ⟨111⟩ direction. Also measured in magnetic field of 0.12%. #1(a): single domain longitudinally saturated by 0.12T magnetic field.	M-6; N-6, 9; S-1, 5.	J.G. Beitchman, C.W. Trussel, and R.V. Coleman (1970).


COBALT
NICKEL
FIGURE 16
W.T. - Ni
F.G. - 1 - Ni
K.K.W. - Ni
F.G. - 2 - Ni
G.H. - 1 - Ni
W.W. - Co
R. - Co
R. - Ni
M.R. - Ni
G.H. - 2 - Ni
F.G. - 3 - Ni
W.P.D. - Co
G.H. - 4 - Ni
G.H. - 3 - Ni
F.G. - 4 - Ni
P.S.J. - Ni
L. - Ni
THERMAL CONDUCTIVITY, W / cm K
TEMPERATURE, K
30
20
10
8
6
5
4
3
2
1
.8
.6
.5
.4
.3
4
5
6
8
10
20
30
40
50
60
80
100
200
300

COBALT
(See FIGURES 15b and 16)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
R.-Co	Johnson, Matthey; spectrographically standardized; RRR(20) = 29.4.	Annealed in vacuum for several hours.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1,2; M-1; S-1, 5.	H.M. Rosenberg (1955).
W.W.-Co	Johnson, Matthey 9484 xx; < 5 ppm Fe; ~ 2 ppm Si; ~ 1 ppm Al; < 1 ppm Cu and Mg; RRR(22) = 64.5.	Prepared from sponge; annealed in vacuum for about 2 hrs. at 700°C. Graph of intrinsic thermal resistivity.	A-1; B-1; C-1; D-4(2); E-1,5; F-4; G-1; L-1,2; N-5; S-1, 5.	G.K. White and S. B. Woods (1957c).
R.N.-Co	Johnson, Matthey; RRR(22)= 66.6.	Annealed at a pressure less than 3×10^{-7}mm for about 3hrs. at 1040°C.	A-1; B-5; C-1; D-3(2); E-4; G-2; M-1; N-6; S-1,2,5.	P. Radhakrishna and M. Nielsen (1965).
W.P.D.-Co	Metallurgie-Hobokan; 99.92% pure; 0.04% Fe; 0.012% Ni; 0.004% C; 0.001% Ca, Cu, and Si; 8 ppm S; 3 ppm Al and Mn; 2 ppm Mg; 1 ppm Pb.	Density of 8805 kg/m^3.	A-1; B-1; C-1; D-1(3); E-2; F-4; G-2; L-1; S-1,5.	K.E. Wilkes, R.W. Powell, and D.P. DeWitt (1969).

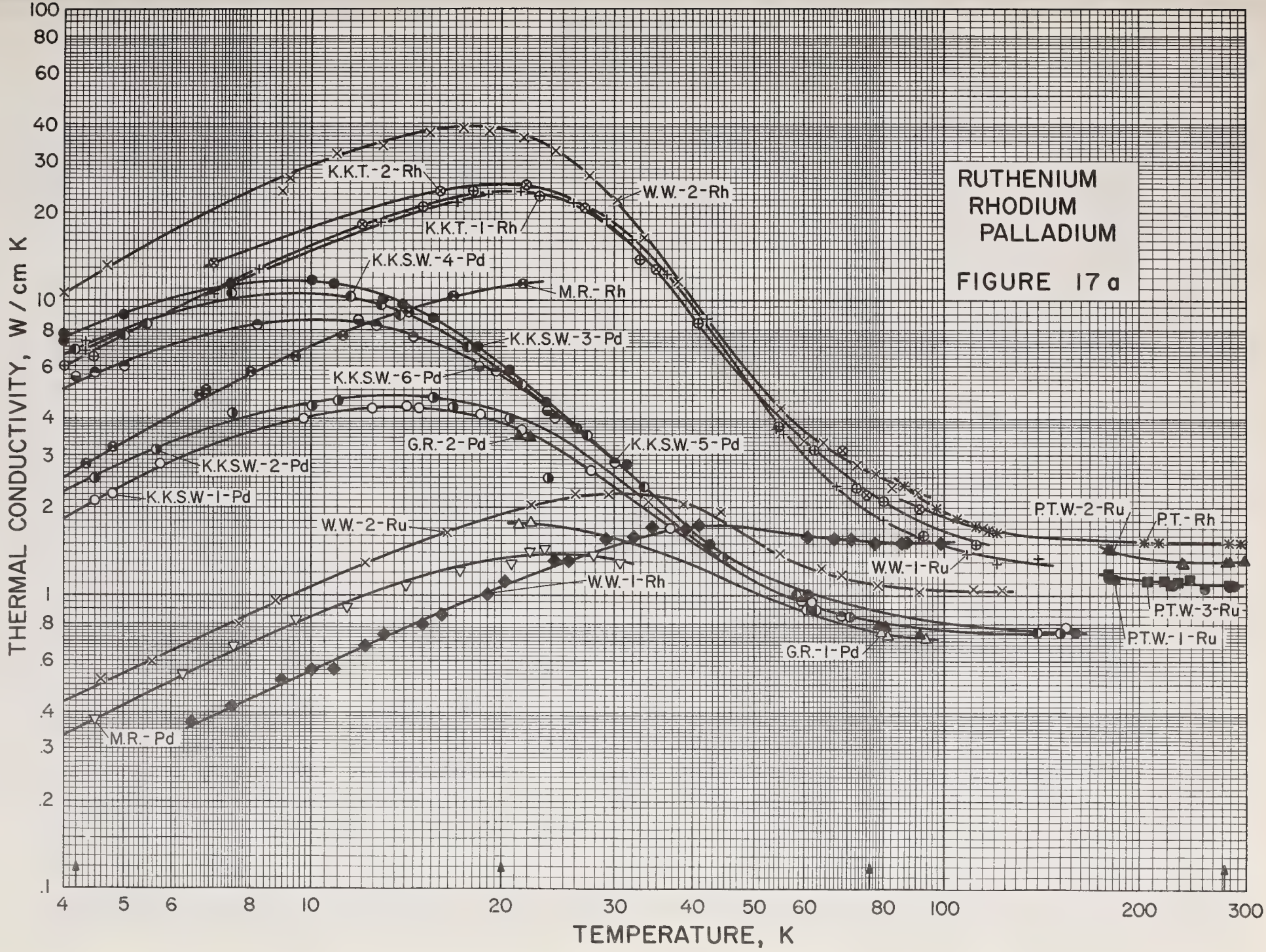
NICKEL

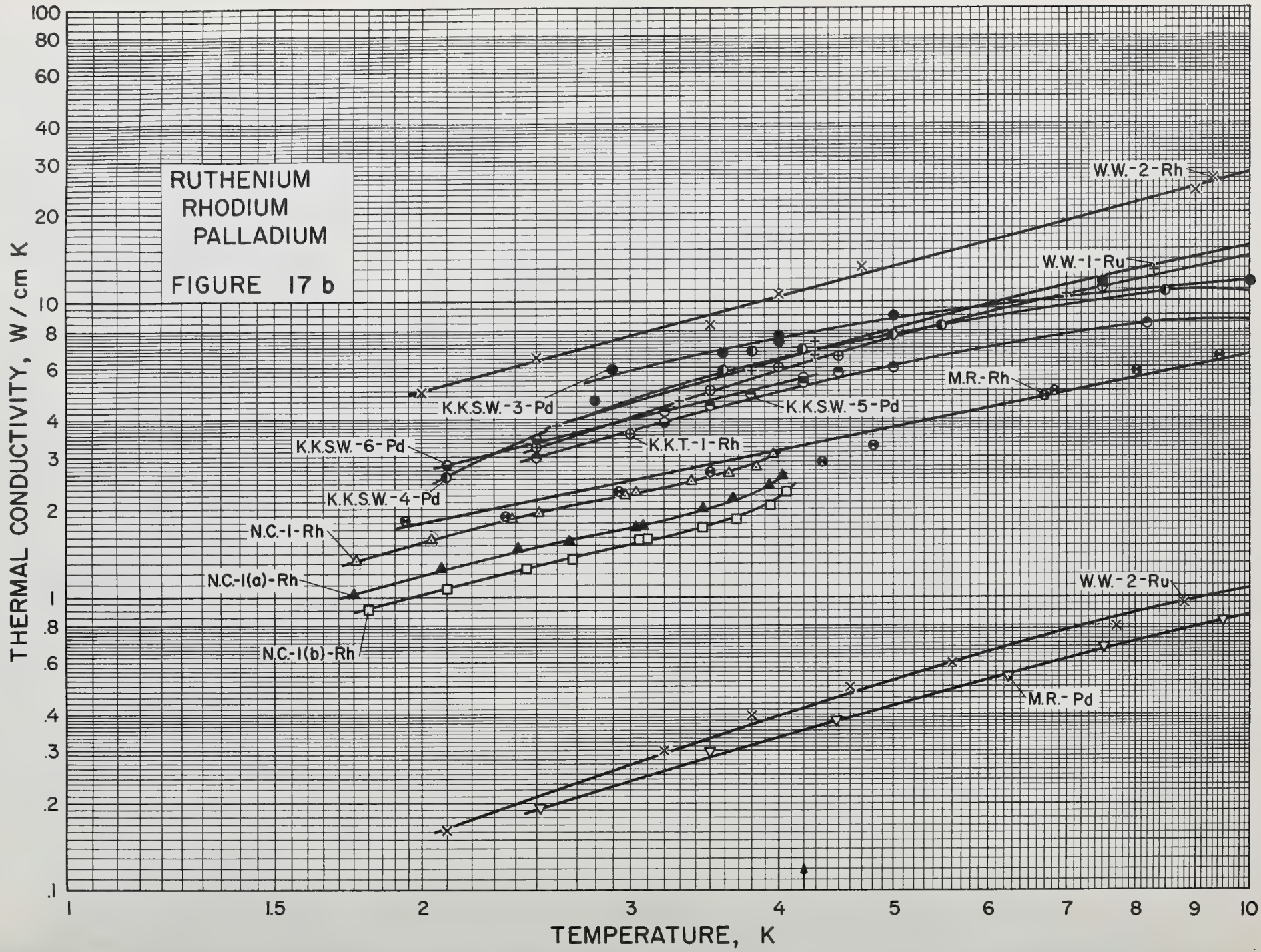
(See FIGURES 15b and 16)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	Basse and Selve;"impure"; 1.36% Co; 1.04% Mn; 0.44% Fe; 0.15% Cu; 0.06% Si; trace of C and Zn.	k = 0.59 at 18°C.	A-4; B-1; C-2, 3; D-1(3); E-1; F-4; G-3; S-1, 2, 3, 5.	W. Jaeger and H. Diesselhorst (1900).
L.-Ni	Johnson, Matthey; 99% pure.	Density of 8.80 at 21°C.	A-1; B-1; C-1; D-2(2); E-2; F-4; G-3; L-1; S-1, 5.	C.H. Lees (1908).
. . . . .	Heraeus.	Electrolytic nickel; k = 1.11 at 80K; k = 0.84 at 273K.	A-1; B-1; C-1; D-1(2); F-4; G-3; P-1; S-1, 5.	A. Eucken and K. Dittrich (1927).
. . . . .	. . . . .	k = 1.18 at 80K; k = 0.827 at 273K.	A-6; B-1; C-1; D-1(2); F-4; G-3.	S. Aoyama and T. Ito (1940).
P.S.J.-Ni	International Nickel Co.; commercially pure; "L" nickel.	. . . . .	A-1; B-1; C-1; D-1(2); E-1; F-2; G-2.	R.W. Powers, D. Schwartz, and H.L. Johnston (1951).
. . . . .	99.4% pure.	As forged; Brinnell hardness of 107; approx. 12-15% lower than P.S.J.-Ni from 93 to 21K; k = 0.18 at 15K.	A-1; B-1; C-1; D-4(1); E-5; F-4; G-2; L-1; M-1.	J. de Nobel (1951).
M.R.-Ni	Johnson, Matthey 4884; 99.997% pure.	Annealed in vacuum for several hours at 1150°C.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1.	K. Mendelssohn and H. M. Rosenberg (1952b).
R.-Ni	Same as above. RRR(20)=80.9.	Same as above. Continuation of the M.R.-Ni curve to higher temperatures.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1; S-1.	H.M. Rosenberg (1955).
K.K.W.-Ni	Johnson, Matthey 4497; > 99.99% pure; faint spectrographic lines of Ag, Al, Ca, Cu, and Si; very faint lines of Li, Mg, and Na; RRR(20)=210.	Annealed in vacuum for 4 hrs. at 750°C. Graph of intrinsic thermal resistivity.	A-1; B-1; C-1; D-4(2); E-2, 5; F-4; G-2; L-1, 2; M-1; N-5; P-1; S-1, 5.	W.R.G. Kemp, P. G. Klemens, and G.K. White (1956).

NICKEL (cont'd)
(See FIGURES 15b and 16)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	Same as above.	Review of the previous paper. Table of intrinsic thermal resistivity.	. . . . .	G.K. White and S.B. Woods (1959).
. . . . .	. . . . .	Graphs of change in thermal resistivity in longitudinal magnetic fields up to 0.17 T and transverse fields up to 2.1 T at 80 K.	. . . . .	L. Berger (1959).
. . . . .	. . . . .	Same as above plus measurements at 4.18 K.	. . . . .	L. Berger and D. Rivier (1962).
G.H.-1, 2, 3, 4-Ni	Johnson, Matthey 893; 16 ppm impurity, mostly Fe and Si. #2: 0.12 atomic percent Cu. #3: 0.8 atomic percent Cu. #4: 0.16 atomic percent Cu.	#1: grains of 0.1 m diameter. #2: very large grains of 1 m diameter. #3: small grains. #4: mostly small grains but a few long grains running from the center.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-2; L-1, 2; N-1; S-1, 2, 5.	D. Grieg and J.P. Harrison (1965).
W.T.-Ni	Bell Telephone Laboratories; RRR ≃ 2500.	Annealed in vacuum (10^{-7} Torr) at 500°C.	L-1, 2; M-1; N-5, 6; S-1, 5.	G.K. White and R.J. Tainsh (1967).
S.-Ni; also see FIGURE 69	Johnson, Matthey 37043; 99.995 pure.	Also measures below 1 K.	A-1; B-5; C-1; D-3(2); E-5; F-4; G-3.	J.K.N. Sharma (1967a).
F.G.-1, 2, 3, 4-Ni	#1: Metals Research Ltd.; RRR = 670. #2: Metals Research Ltd.; 0.3 Pd (atomic %); RRR = 140. #3: 0.5 Fe (atomic %). #4: 0.3 Cu (atomic%); RRR = 27.	Annealed for 15 hrs. at 850°C. Table of intrinsic thermal resistivity. See also NICKEL ALLOYS Table.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-2; L-1, 2; M-1, 2; N-1, 5, 6; P-1; Q-1, 3; R-2; S-1, 5.	T. Farrell and D. Greig (1969).
M.K.R.-Ni	99.9 pure; C, Fe, and Si impurities.	Single crystal; grown by Bridgman method in alumina crucible; annealed at 930°C for 48 hrs; rod axis parallel to ⟨111⟩ crystal axis.	A-1; B-1; C-1; D-3(2); E-5; G-2; M-1; Q-1; S-1, 5.	M.A. Mitchell, P.G. Klemens, and C.A. Reynolds (1971).


RUTHENIUM
RHODIUM
PALLADIUM
FIGURE 17 a
THERMAL CONDUCTIVITY, W / cm K
TEMPERATURE, K
K.K.T.-2-Rh
W.W.-2-Rh
K.K.T.-1-Rh
K.K.S.W.-4-Pd
M.R.-Rh
K.K.S.W.-3-Pd
K.K.S.W.-6-Pd
G.R.-2-Pd
K.K.S.W.-5-Pd
K.K.S.W.-2-Pd
K.K.S.W-1-Pd
W.W.-2-Ru
W.W.-1-Rh
P.T.W.-2-Ru
P.T.-Rh
W.W.-1-Ru
P.T.W.-3-Ru
P.T.W.-1-Ru
G.R.-1-Pd
M.R.-Pd


RUTHENIUM
RHODIUM
PALLADIUM
FIGURE 17 b
THERMAL CONDUCTIVITY, W / cm K
TEMPERATURE, K
100
80
60
40
30
20
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
1
1.5
2
3
4
5
6
7
8
9
10
W.W.-2-Rh
W.W.-1-Ru
M.R.-Rh
K.K.S.W.-3-Pd
K.K.S.W.-5-Pd
K.K.S.W.-6-Pd
K.K.T.-1-Rh
K.K.S.W.-4-Pd
N.C.-1-Rh
N.C.-1(a)-Rh
N.C.-1(b)-Rh
W.W.-2-Ru
M.R.-Pd

RUTHENIUM

(See FIGURES 17a and 17b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
W.W.-1,2-Ru	Baker Platinum Co.; ~ 99.99% pure; no obvious spectroscopic lines of Cu, W, or other major impurities. #1: RRR(22) = 467. #2: RRR(22)= 36.1.	Arc-melted from powder. Graph of intrinsic thermal resistivity. #1: specific density of 12.25 at 22°C. #2: specific density of 12.0 at 22°C; did not show holes under examination. #1 was harder than #2. #2 showed some slight evidence of the presence of a decomposed phase. Grain size of both ~ 1 mm.	A-1; B-3; C-1; D-4(2); E-1,5; F-4; G-1; L-1,2; M-1; N-1; S-1,5.	G.K. White and S.B. Woods (1958).
. . . . .	. . . . .	Review of previous paper. Table of intrinsic thermal resistivity.	. . . . .	G.K. White and S.B. Woods (1959).
. . . . .	International Nickel Co.(Mond) Ltd.; 0.02% Os; 0.0025% Fe; 0.007% Rh; < 0.001% Pd and Sb; RRR(22) = 400.	Table of intrinsic thermal resistivity. Good agreement with W.W.-1-Rh.	. . . . .	R.J. Tainsh and G. K. White (1964).
P.T.W.-1,2,3-Ru	International Nickel Co.(Mond) Ltd.; 300 ppm Os; 60 ppm Fe; 30 ppm Ni; 10 ppm Pd (source material). #1: RRR = 94. #2: RRR = 76.5. #3: RRR = 388.	#1: prepared by pressing powder, then prepared as single crystal by electron-bombardment zone melting using an oriented seed crystal; possibly could contain traces of Mo and W as a result of treatment; axis of bar perpendicular to prism axis of crystal; density of 12.38 g/cm^3. #2: same boule and treatment as #1; axis of bar parallel to prism axis of crystal; density of 12.38 g/cm^3. #3: polycrystalline bar pressed at 20 tons/in^2, then sintered in vacuum at 1920 K and hot forged; density of 12.24 g/cm^3.	A-1; B-1; C-1; D-1(2); F-4; G-2; L-1; N-4; S-1,5.	R.W. Powell, R.P. Tye, and M.J. Woodman (1967).

RHODIUM

(See FIGURES 17a and 17b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	k = 0.88 at 17°C; specific density of 12.505.	A-5; B-5; C-1; D-2(2); E-2; F-5; G-3; S-1.	T. Barratt (1914).
. . . . .	. . . . .	Same as above.	Same as above.	T. Barratt and R.M. Winter (1925).
. . . . .	Heraeus; "pure".	Annealed in vacuum for 10 minutes at 1030°C.; k = 2.15 at 83K; k = 23.8 at 21K.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-3; L-1,2; P-1; S-1,5.	E. Grüneisen and E. Goens (1927).
M.R.-Rh	Johnson, Matthey 2357; 99.995% pure.	Unannealed wire.	A-1; B-5; C-1; D-4(2); E-4; F-4; G-2; L-1,2; M-1.	K. Mendelssohn and H.M. Rosenberg (1952b).
. . . . .	Same as above. RRR(20)= 63.1.	Review of previous paper.	Same as above.	H.M. Rosenberg (1955).
P.T.-Rh	Johnson, Matthey; 0.03-0.1% Ir; 0.001 - 0.003% Pd; 0.005% Fe; 0.002-0.005% Ag.	Annealed at 1610K. Density of 12.45 g/cm^3.	A-1; B-1; C-1; D-1(3); F-4; G-2; L-1; S-1,5.	R.W. Powell and R.P. Tye (1955).
. . . . .	. . . . .	Graph of intrinsic thermal resistivity. Completed results in following paper.	. . . . .	G.K. White (1956).
W.W.-1,2-Rh	#1: Baker Platinum Co.; > 99.9% pure; RRR(22) = 12. #2: Johnson, Matthey 8208; > 99.997% pure; 20 ppm Fe; 5 ppm Cu; RRR(22)= 572.	#1: annealed in vacuum at 1050°C. #2: annealed at 1300°C. Graph of intrinsic thermal resistivity.	A-1; B-1; C-1; D-4(2); E-1,5; F-4; G-1; L-1,2; M-1; N-5; S-1,5.	G.K. White and S.B. Woods (1957a).
. . . . .	. . . . .	Review of previous paper. Table of intrinsic thermal resistivity.	. . . . .	G.K. White and S.B. Woods (1959).
K.K.T.-1,2-Rh	Specimens from rod of Grüneisen and Goens (1927).	#1: previously annealed in vacuum for 10 minutes at 1030°C. #2: annealed in vacuum for 5 hrs. at 1400°C and cooled slowly.	A-1; B-1,2; C-1; D-4(2); E-2,5; F-4; G-2; L-1,2,9; M-1; N-5; S-1,5.	W.R.G. Kemp, P.G. Klemens, and R.J. Tainsh (1959 a).
. . . . .	Same as P.T.-Rh above. RRR = 180.	Review of P.T.-Rh above.	. . . . .	R.W. Powell, R.P. Tye, and M. J. Woodman (1962).

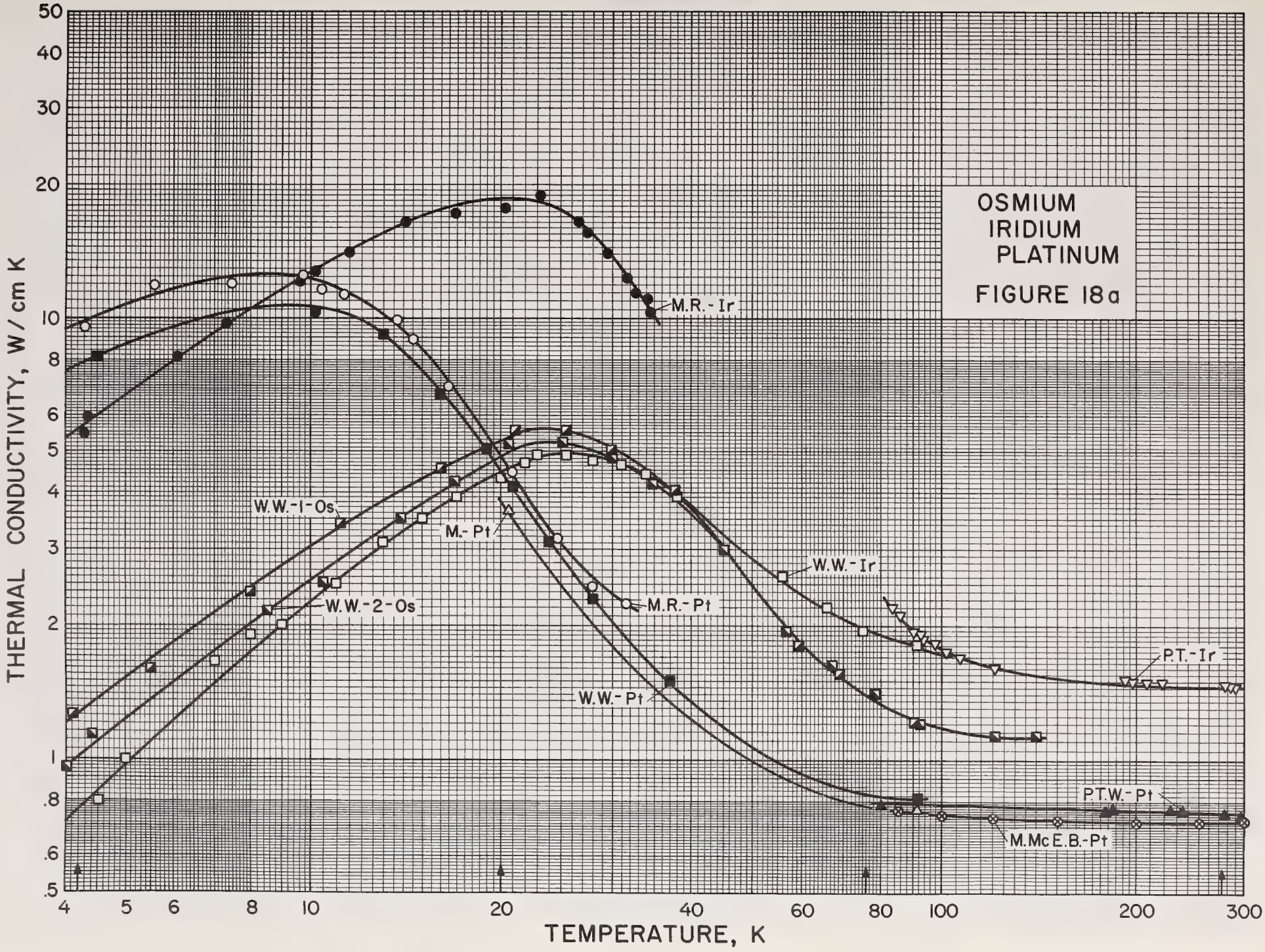
RHODIUM (cont'd)
(See FIGURES 17a and 17b)

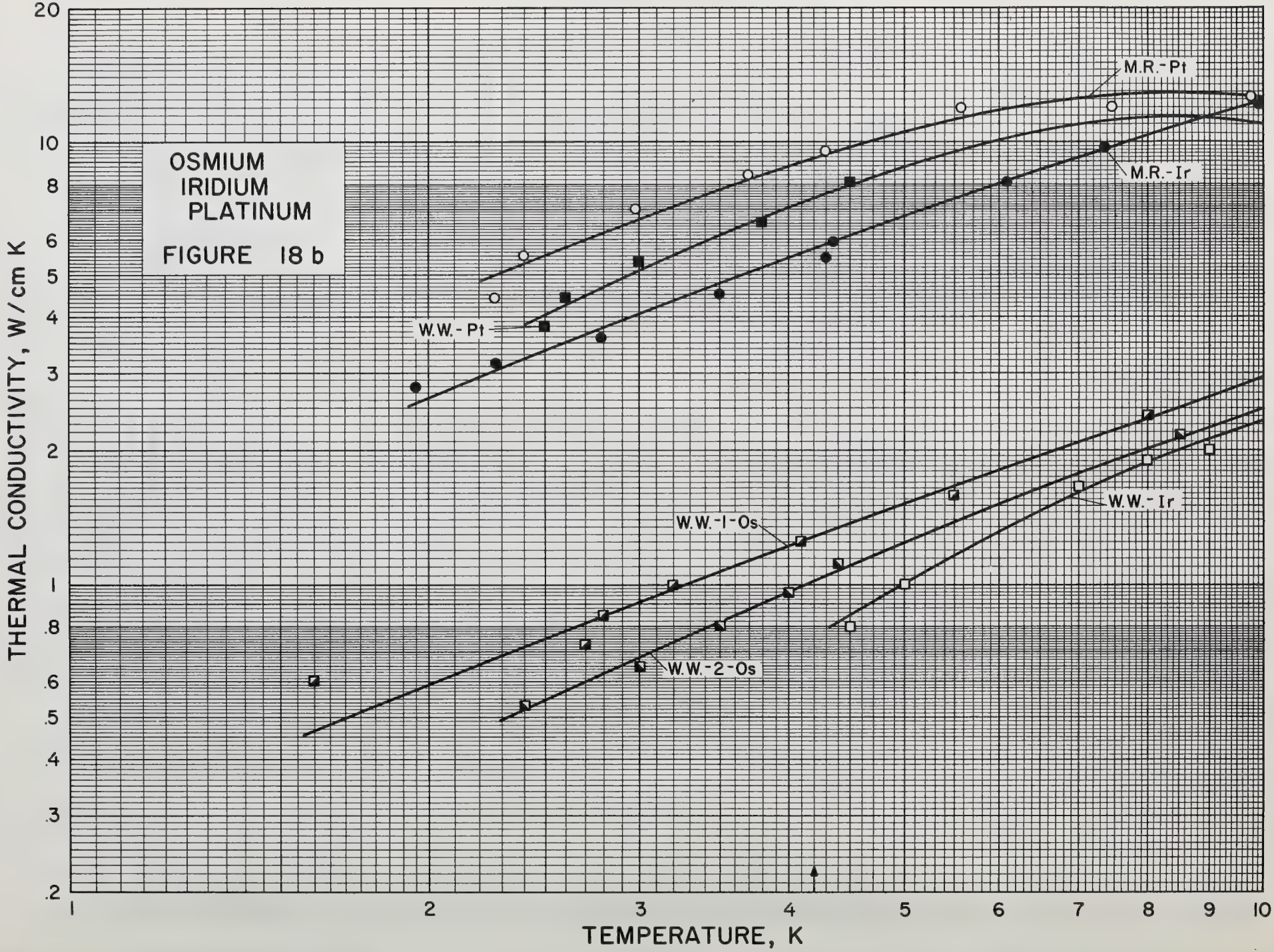
CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	Same as P. T.-Rh above.	Review of P. T.-Rh above.	. . . . .	R. W. Powell, R. P. Tye, and M. J. Woodman (1967).
N. C.-1, 1(a), 1(b) - Rh	Johnson, Matthey No. 2357 Rh, 99.9995% pure.	#1: in zero field; considered unannealed. #1(a): in a transverse magnetic field of 1.07 T. #1(b): in a transverse magnetic field of 1.75 T. Also measured at two other intermediate field strengths, with intermediate results. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-3(2); G-2; L-1, 2; M-1; N-2; Q-1; S-1, 5.	N. S. Natarajan and M. S. R. Chari (1970b).

PALLADIUM

(See FIGURES 17a and 17b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	"Chemically pure"	k = 0.7 at 18°C.	A-4; B-1; C-2, 3; D-1(3); E-1; F-4; G-3; S-1, 2, 3, 5.	W. Jaeger and H. Diesselhorst (1900).
. . . . .	Heraeus.	k = 0.67 at 25°C.	A-4; B-1; C-3; G-2; M-2; S-1, 5.	F. A. Schulze (1911).
. . . . .	. . . . .	k = 0.42 at 17°C for commercial palladium; k = 0.60 at 17°C for "pure".	A-5; B-5; C-1; D-2(2); E-2; F-5; G-3; S-1.	T. Barratt (1914).
. . . . .	. . . . .	Same as above.	Same as above.	T. Barratt and R. M. Winter (1925).
G.R.-1, 2-Pd	Heraeus; "pure".	#1: unannealed. #2: cold-drawn; annealed for 2 hrs. at 360°C.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-3; L-1; P-1; S-1, 5.	E. Grüneisen and H. Reddemann (1934).
M.R.-Pd	Johnson, Matthey 2134; 99.995% pure.	Annealed in vacuum for several hrs. at 1150°C.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1.	K. Mendelssohn and H.M. Rosenberg (1952b).
. . . . .	Same as above. RRR(20) = 34.1.	Review of previous paper.	Same as above.	H.M. Rosenberg (1955).
K.K.S.W.-1, 2, 3, 4, 5, 6-Pd	Johnson, Matthey 2928; > 99.995% pure; strong spectroscopic lines of Ag; faint lines of Ca, Cu, Si, and Mg. RRR(20) = 590.	#1: strained (as received). #2: annealing of #1 at 250°C (all annealing carried out in vacuum for about 4 hrs.). #3: annealing of #2 at 450°C. #4: annealing of #3 at 650°C. #5: annealing of #4 at 1000°C. #6: drawing of #5, annealed at 450°C.	A-1; B-1; C-1; D-4(2); E-1, 5; F-4; G-1; L-1, 2, 3, 9; M-1; N-5; S-1, 5.	W.R.G. Kemp, P.G. Klemens, A.K. Speedhar, and G.K. White (1955).
. . . . .	. . . . .	Review of previous paper. Table of intrinsic thermal resistivity.	. . . . .	G.K. White and S.B. Woods (1959).
See FIGURE 69	. . . . .	Measured below 1 K.	. . . . .	J.K.N. Sharma (1967 a).


OSMIUM
IRIDIUM
PLATINUM
FIGURE 18a
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
50
40
30
20
10
8
6
5
4
3
2
1
.8
.6
.5
4
5
6
8
10
20
40
60
80
100
200
300
M.R.-Ir
W.W.-1-Os
M.-Pt
W.W.-2-Os
W.W.-Ir
M.R.-Pt
P.T.-Ir
W.W.-Pt
P.T.W.-Pt
M.McE.B.-Pt


OSMIUM
IRIDIUM
PLATINUM
FIGURE 18 b
M.R.-Pt
M.R.-Ir
W.W.-Pt
W.W.-Ir
W.W.-1-Os
W.W.-2-Os
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
20
10
8
6
5
4
3
2
1
.8
.6
.5
.4
.3
.2
1
2
3
4
5
6
7
8
9
10

OSMIUM

(See FIGURES 18a and 18b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
W.W.-1,2-Os	#1: Baker Platinum Co.; purity comparable to #2; RRR(22) = 160. #2: Johnson, Matthey; > 99.995% pure; RRR(22) = 93.	#1: arc-melted from powder using an osmium-cathode, remelted and ground. #2: prepared from powder with an osmium-cathode in the arc furnace. Graph of intrinsic thermal resistivity.	A-1; B-1,3; C-1; D-4(2); E-1,5; F-4; G-1; L-1,2; M-1; N-1; P-1; S-1,5.	G.K. White and S.B. Woods (1958 a).
. . . . .	. . . . .	Review of previous paper. Table of intrinsic thermal resistivity.	. . . . .	G.K. White and S.B. Woods (1959).

IRIDIUM
(See FIGURES 18a and 18b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	k = 0.59 at 17°C. Specific density of 22.33.	A-5; B-5; C-1; D-2(2); E-2; F-5; G-3; S-1.	T. Barratt (1914).
. . . . .	. . . . .	Same as above.	Same as above.	T. Barratt and R. M. Winter (1925).
M.R.-Ir	Johnson, Matthey 3441; 99.995% pure.	Annealed in vacuum for several hrs. at 1150°C.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1,2; M-1.	K. Mendelssohn and H.M. Rosenberg (1952b).
. . . . .	Same as above. RRR(20)=225.	Review of previous paper.	Same as above.	H.M. Rosenberg (1955).
P.T.-Ir	Johnson, Matthey; 0.02-0.05% Rh; 0.002-0.005% Ru; 0.001% Pd.	Annealed at 1310°C. Density of 22.49 g/cm^3.	A-1; B-1; C-1; D-1(3); F-4; G-2; L-1; S-1,5.	R.W. Powell and R.P. Tye (1955).
W.W.-Ir	Johnson, Matthey 10371; > 99.98% pure; 0.01% Rh; 0.002% Pt; 0.001% Cu; RRR(22) = 49.5.	Annealed in vacuum at 1300°C. Graph of intrinsic thermal resistivity.	A-1; B-1; C-1; D-4(2); E-1, 5; F-4; G-1; L-1,2; M-1; N-5; S-1.	G.K. White and S. B. Woods (1957a).
. . . . .	. . . . .	Review of previous paper. Graph and table of intrinsic thermal resistivity.	. . . . .	G.K. White and S. B. Woods (1959).
. . . . .	Same as P.T.-Ir above. RRR = 86.	Review of P.T.-Ir above.	. . . . .	R.W. Powell, R.P. Tye, and M.J. Woodman (1962).
. . . . .	Same as P.T.-Ir above.	Review of P.T.-Ir above.	. . . . .	R.W. Powell, R.P. Tye, and M.J. Woodman (1967).

PLATINUM

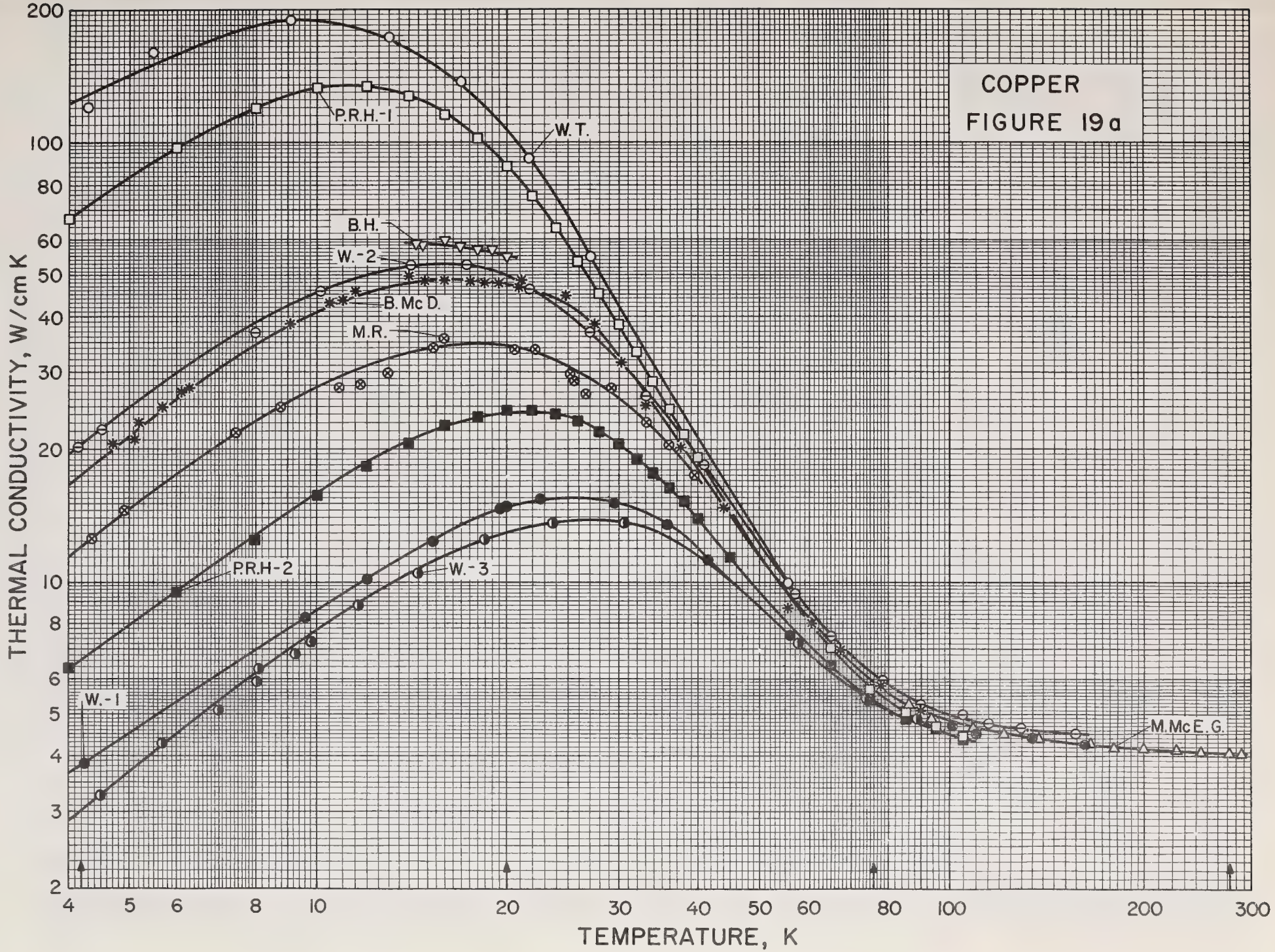
(See FIGURES 18a and 18b)

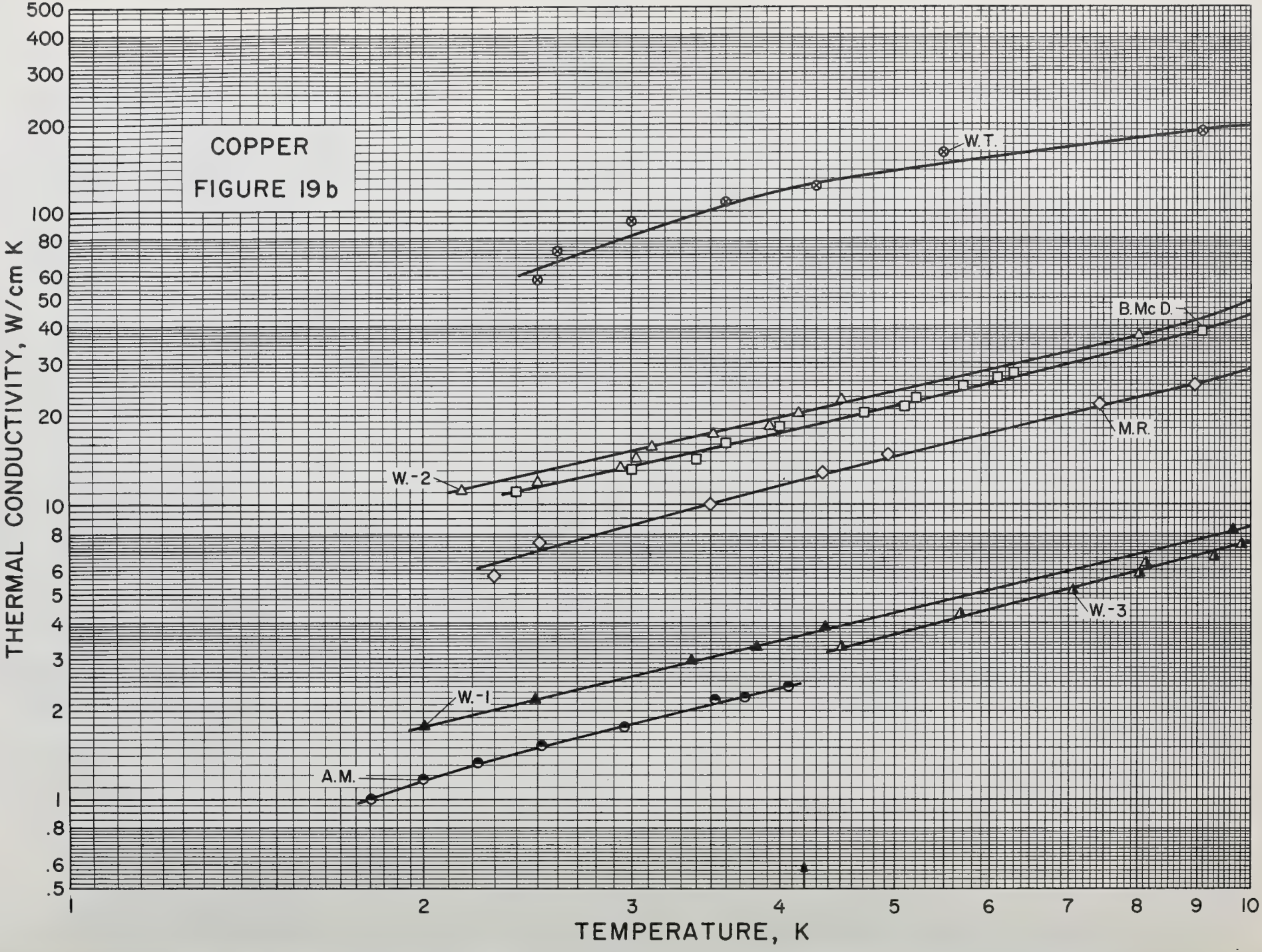
CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	"Pure".	k = 0.69 at 18°C.	A-4; B-1; C-2, 3; D-1(3); E-1; F-4; G-3; S-1, 2, 3, 5.	W. Jaeger and H. Diesselhorst (1900).
. . . . .	Heraeus.	k = 0.70 at 25°C.	A-4; B-1; C-3; G-2; M-2; S-1, 5.	F. A. Schulze (1911).
. . . . .	. . . . .	k = 0.69 at 17 °C.	A-5; B-1; C-1; D-2(2); E-2; F-5; G-3; S-1.	T. Barratt (1914).
M.-Pt	Heraeus; "very pure"; RRR = 160.	Electrically annealed to white hot.	A-4; B-1; C-3; D-2(2); E-5; F-4; G-2; L-1; M-1; P-1; S-1, 2, 5.	W. Meissner (1915).
. . . . .	. . . . .	Same as T. Barratt (1914) above.	Same as T. Barratt (1914) above.	T. Barratt and R. M. Winter (1925).
. . . . .	Heraeus. #1: "very pure". #2: "less pure".	Annealed. #1: same wire as M.-Pt. Same results as M.-Pt at 21 and 83 K. #2: k = 2.96 at 21 K.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-3; L-1, 2; P-1; S-1, 5.	E. Grüneisen and E. Goens (1927).
. . . . .	Heraeus.	Same wire as M.-Pt. k = 4.25 at 21 K; measured in transverse magnetic field up to 1.22 T. Graph of field dependence.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-3; L-1; M-1; N-2, 4; P-1; S-1, 5.	E. Grüneisen and H. Adenstedt (1938).
. . . . .	. . . . .	k = 0.693 at 90 K; k = 0.680 at 194.5 K; k = 0.703 at 273 K.	A-4; B-5; C-3; D-2; E-5, 8; F-4; G-3.	W. G. Kannuluik and E. H. Carman (1951).
M.R.-Pt	Johnson, Matthey 2157b; 99.999% pure.	Annealed in vacuum for several hours.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1.	K. Mendelssohn and H. M. Rosenberg (1952b).
. . . . .	Same as above. RRR(20) = 202.	Review of previous paper.	. . . . .	H. M. Rosenberg (1955).

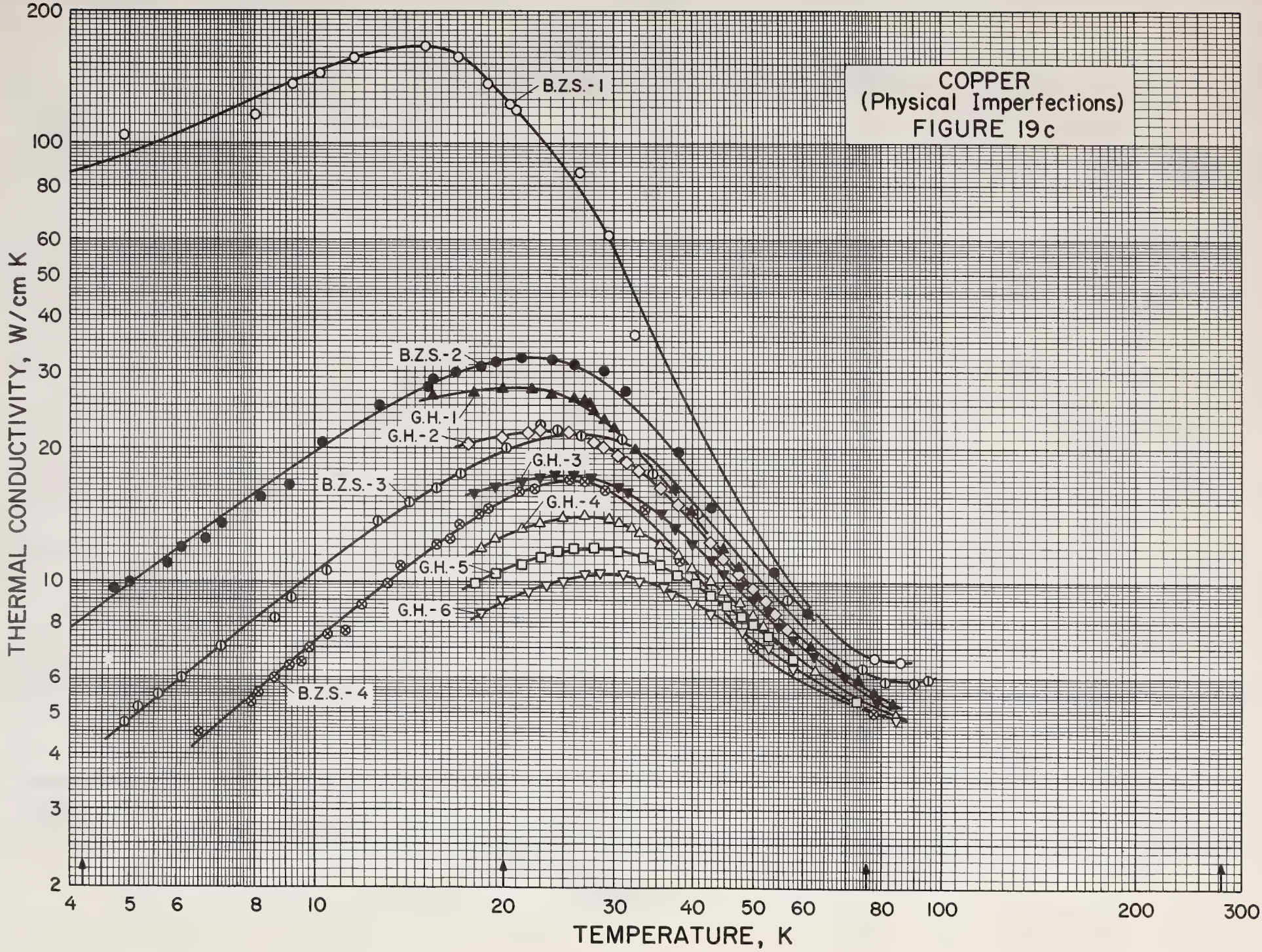
PLATINUM (cont'd)

(See FIGURES 18a and 18b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
W.W.-Pt	Baker Platinum Co.; > 99.99% pure; RRR(25) = 830.	Annealed in vacuum at 1050°C. Graph of intrinsic thermal resistivity.	A-1; B-1; C-1; D-4(2); E-1,5; F-4; G-1; L-1,2; M-1; N-5; S-1.	G.K. White and S.B. Woods (1957a).
. . . . .	. . . . .	Review of previous paper. Table of intrinsic thermal resistivity.	. . . . .	G.K. White and S.B. Woods (1959).
. . . . .	Heraeus; 99.98% pure; ~ 30 ppm Ir; 21-23 ppm Ca and Rh; 15-17 ppm Aℓ and Pd; 11 ppm Au; 7-9 ppm Ag and Mg; 4-6 ppm Cu and Fe.	Melted in a graphite crucible, cooled, cold-worked with a volume reduction of 20%. Annealed for 2 hrs. at 600°C. k = 0.703 at 0°C; k = 0.704 at 17°C; k = 0.705 at 21.1°C. Density of 21.32 g/mℓ at 21°C.	A-1; B-2; C-1; D-1(6); E-2,7; F-4; G-2; L-1.	K.H. Bode (1964).
. . . . .	. . . . .	Result at 0°C about 2% lower than Bode (1964).	. . . . .	V.S. Kobyushko, B. A. Merisov, and V. I. Khotkevich (1965).
M.McE.B.-Pt	National Bureau of Standards; 99.98% pure (E-2 grade); 10-100 ppm Ag and Pd; < 10 ppm Fe and Mg; RRR = 426. Another specimen was same as P.T.W.-Pt below; 99.999% pure; RRR = 600.	Annealed in air for $5\frac{1}{2}$ hrs. at 770°C; furnace cooled at 120°C/hr.; damaged; reannealed $1\frac{1}{2}$ hrs. at 680°C; furnace cooled at 90°C/hr.; turned and ground. Density of 21.384 g/cm^3 at 21°C; grain size about 0.2 mm; Vikers pyramid diamond hardness (10 kg) of 36.5-38.0. The other specimen was about 1% lower than the curve M.McE.B.-Pt; it was also 3% lower than the results reported for P.T.W.-Pt.	A-1; B-1; C-1; D-1(2); E-1; F-1; G-1; L-1,2; S-1,2,5.	J.P. Moore, D.L. McElroy, and M. Barisoni (1966).
P.T.W.Pt	Johnson, Matthey; 1 ppm Cu and Fe; < 1 ppm Pd; RRR = 740.	Annealed at 1273 K. Density of 21.51 g/cm^3.	A-1; B-1; C-1; D-1(2); F-4; G-2; L-1; S-1,5.	R.W. Powell, R.P. Tye, and M.J. Woodman (1967).
See FIGURE 69	. . . . .	Measured below 1 K.	. . . . .	J.K.N. Sharma (1967 a).


COPPER
FIGURE 19a
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
200
100
80
60
50
40
30
20
10
8
6
5
4
3
2
4
5
6
8
10
20
30
40
50
60
80
100
200
300
P.R.H.-1
W.T.
B.H.
W.-2
B. Mc D.
M.R.
P.R.H-2
W.-3
W.-1
M.Mc E. G.


COPPER
FIGURE 19b
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
W.T.
B.Mc D.
M.R.
W.-2
W.-3
W.-1
A.M.
500
400
300
200
100
80
60
50
40
30
20
10
8
6
5
4
3
2
1
.8
.6
.5
1
2
3
4
5
6
7
8
9
10


COPPER
(Physical Imperfections)
FIGURE 19c
B.Z.S.-1
B.Z.S.-2
G.H.-1
G.H.-2
G.H.-3
B.Z.S.-3
G.H.-4
G.H.-5
G.H.-6
B.Z.S.-4
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
200
100
80
60
50
40
30
20
10
8
6
5
4
3
2
4
5
6
8
10
20
30
40
50
60
80
100
200
300

COPPER

(See FIGURES 19a–19c ; also 43a-43c and 43e)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	"Pure".	k = 3 at 0°C.	A-5; B-1; C-1; D-7(9); F-5; G-3; S-1, 3, 5.	L. Lorenz (1881 a).
. . . . .	"Pure".	k = 3.9 at 18°C. Specific density of 8.92.	A-1; B-1; C-2; D-1(2); F-5; G-3; S-1, 3, 5.	E. Grüneisen (1900).
. . . . .	#2: Kahlbaum; traces of Fe and Zn, < 0.05%. #3: Hesse Söhne; 0.05% Pb; traces of Fe and Ni.	#2: cast; k = 3.84 at 18°C; specific density of 8.65. #3: drawn; k = 3.68 at 18°C; specific density of 8.88.	A-4; B-1; C-2, 3; D-1(3); E-1; F-4; G-3; S-1, 2, 3, 5.	W. Jaeger and H. Diesselhorst (1900).
. . . . .	. . . . .	"Soft drawn, high conductivity"; results between 100 and 273 K are within 5% of P.S.J. curve. Specific density of 8.84.	A-1; B-1; C-1; D-2(2); E-2; F-4; G-3; L-1; S-1, 2, 3, 5.	C. H. Lees (1908).
. . . . .	. . . . .	Preliminary results; thorough discussion in the following reference.	. . . . .	W. Meissner (1914).
. . . . .	#1: Siemens and Halske; RRR = 380. #2: Reichsanstalt; RRR = 85.	Electrolytic. #1: diamagnetic; k = 17.6 at 20.7 K, k = 4.95 at 90.7 K, k = 3.92 at 273 K and 293 K. #2: paramagnetic; k = 16.8 at 21.5 K, k = 4.6 at 91.4 K, k = 3.83 at 273 K and 298 K.	A-4; B-5; C-3; D-2(2); E-5; F-4; G-2; L-1; M-1; P-1; S-1, 2, 4, 5.	W. Meissner (1915).
. . . . .	#1: "very pure"; RRR = 834. #2: "technically pure"; RRR = 48.	#1: natural single crystal from Lake Michigan; results uncertain due to very small size of specimen. #2: approximately on W.-3 curve down to 22 K.	A-1; B-1; C-1; D-1(2); E-1; F-5; G-3; L-1; M-1; S-1, 5.	R. Schott (1916).
. . . . .	. . . . .	See results under Commercial Coppers and Copper Alloys.	. . . . .	E. Sedström (1919).
. . . . .	. . . . .	See results under Commercial Coppers and Copper Alloys.	. . . . .	E. Sedström (1924).
. . . . .	. . . . .	Measured 15 specimens of various crystal structure, purity, and annealing. Thermal conductivity values at 21 K varied from 11.4 to 88. Also measured values at 83 K.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-3; L-1, 2; M-4; P-1; S-1, 5.	E. Grüneisen and E. Goens (1927).

COPPER (cont'd)

(See FIGURES 19a–19c ; also 43a-43c and 43e)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	General Electric.	Single crystal; between 100 and 292 K, the values are within 5% of M.McE.G.	A-1; B-1; C-1; D-1(2); E-2; F-4; G-3; L-1; S-1,5.	W. G. Kannuluik and T. H. Laby (1928).
. . . . .	. . . . .	Measured 1 pure and 19 alloyed specimens at 20 and 90 K. See results under Copper Alloys.	. . . . .	E. Grüneisen and H. Reddemann (1934).
. . . . .	. . . . .	Method for measuring thermal conductivity of metal foils. Results agree within 2% of previous workers.	. . . . .	A. Eucken and H. Warrentrup (1935).
B.H.	. . . . .	Graph of intrinsic thermal resistivity.	A-1; B-5; C-1; D-2,4,5(2); E-2; F-4; G-3; L-1,2; M-1; S-1,5.	H. Bremmer and W. J. de Haas (1936a); see also W. J. de Haas and T. Biermasz (1936).
. . . . .	. . . . .	Measured effect of magnetic field on thermal conductivity up to 1.22 T.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-3; L-1; M-1; N-2,4; P-1; S-1,5.	E. Grüneisen and H. Adenstedt (1938).
A.M.	Johnson, Matthey 1562; free of O_2; 0.003% Ag, Ni, and Pb; RRR = 28.2.	Machined and annealed.	A-1; B-1; C-1; D-2(2); E-5; F-4; G-2; M-1; S-1,5.	J. F. Allen and E. Mendoza (1947).
. . . . .	. . . . .	Annealed electrical wire. k = 7.5 at 15 K; k = 8.8 at 20 K.	A-1; B-5; C-2; D-5(1); E-5; F-4; G-3; M-1.	K. R. Wilkinson and J. Wilks (1949).
See FIGURE 43b	. . . . .	See results under Commercial Coppers.	. . . . .	R. W. Powers, D. Schwartz, and H. L. Johnston (1951).
B.McD.	Johnson, Matthey 4234; 5 ppm Ag; < 4 ppm Pb; < 3 ppm Ni.	Cold-drawn, annealed 6 hrs. at 450°C in helium gas.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1,2; M-1,6; S-1,5.	R. Berman and D.K.C. Mac Donald (1952).
M.R.	Johnson, Matthey 4234; 99.999 % pure.	Annealed in vacuum for several hours at 800°C.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1,2; M-1.	K. Mendelssohn and H. M. Rosenberg (1952a).

COPPER (cont'd)

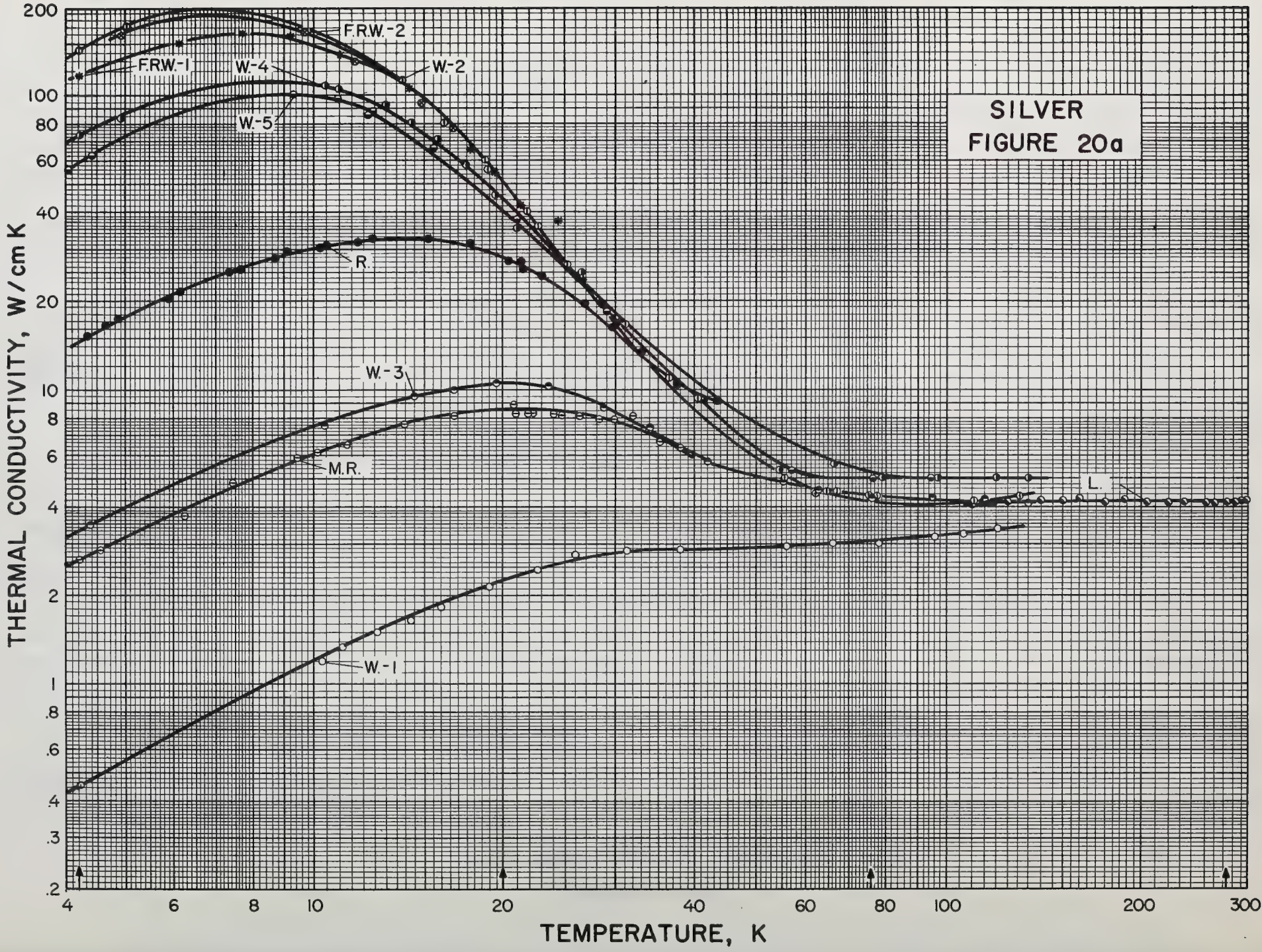
(See FIGURES 19a–19c ; also 43a-43c and 43e)

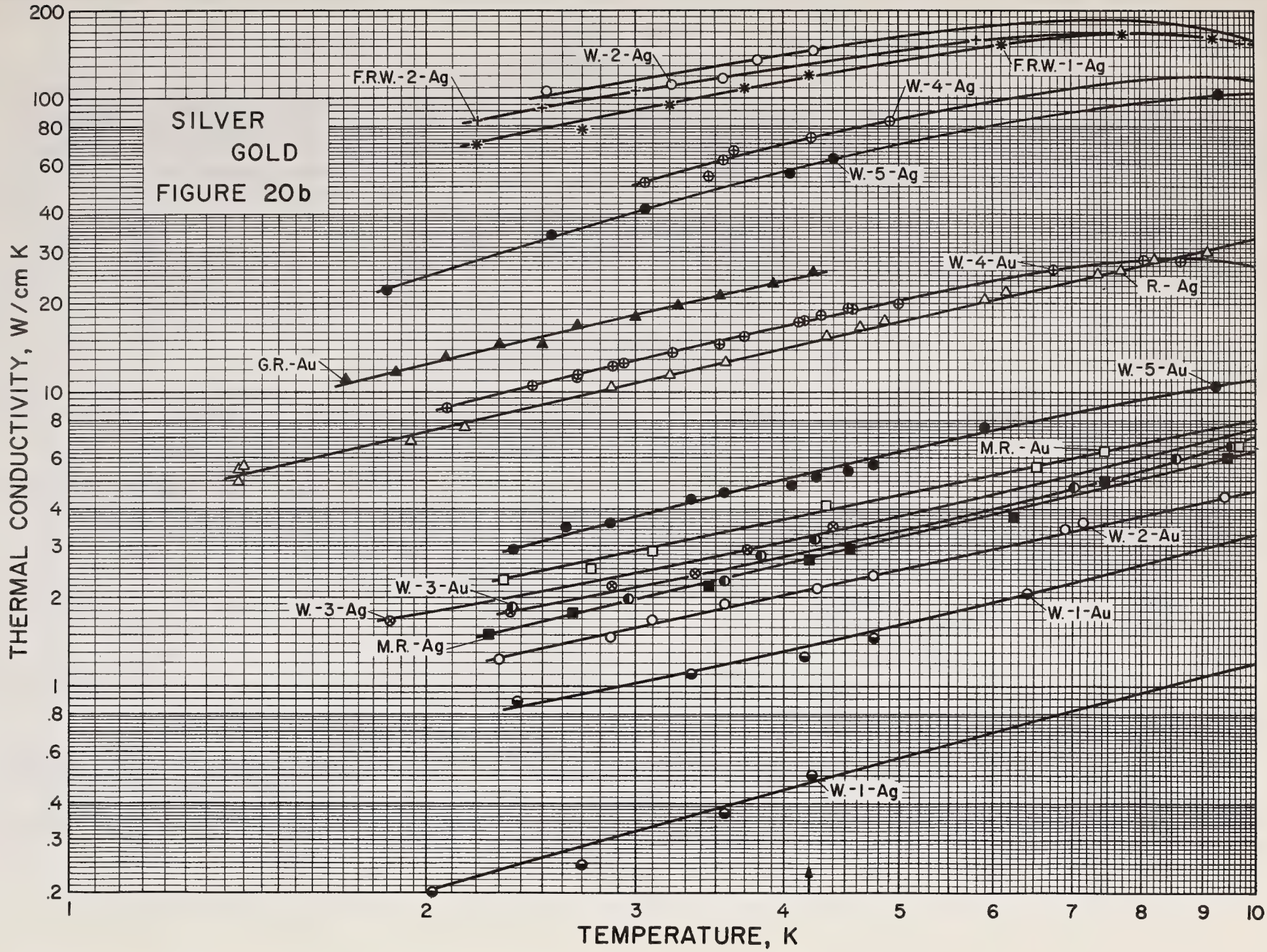
CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
See FIGURES 43e and 71	. . . . .	See results under Commercial Coppers and Copper Alloys; also measured below 1 K.	. . . . .	J. Nicol and T. P. Tseng (1953).
W.-1, 2, 3	Johnson, Matthey 4272; 99.999 % pure; 5 ppm Ag; 4 ppm Pb; < 3 ppm Ni; barely visible spectrographic lines of Fe.	#1: as drawn. #2: #1 after annealing in vacuum for 3 hrs. at 550°C. #3: as drawn, same as #1. Graph of intrinsic thermal resistivity.	A-1; B-1; C-1; D-4(2); E-1, 5; F-4; G-1; L-1, 2; N-1; S-1,5.	G. K. White (1953 c).
See FIGURE 43e	. . . . .	See results under Commercial Coppers and Copper Alloys.	. . . . .	T. P. Tseng (1954).
See FIGURE 43b	. . . . .	Graph of electronic and lattice thermal conductivity of dilute copper alloys; see results under Commercial Coppers and Copper Alloys.	. . . . .	G. K. White and S. B. Woods (1954); see also G. K. White and S. B. Woods (1955).
. . . . .	Same as M.R. above. RRR(20) = 85.3.	Review of M.R. above.	. . . . .	H. M. Rosenberg (1955).
See FIGURE 75	. . . . .	Measured below 1 K.	. . . . .	N. E. Phillips (1955).
See FIGURES 43a and 43b	. . . . .	See results under Commercial Coppers and Copper Alloys.	. . . . .	N. V. Zavaritskii and A. C. Zeldovich (1956).
See FIGURE 43b	. . . . .	See results under Commercial Coppers and Copper Alloys.	. . . . .	R. L. Powell, W. M. Rogers, and D. O. Coffin (1957).
See FIGURE 43b	. . . . .	See results under Commercial Coppers and Copper Alloys.	. . . . .	R. L. Powell, H. M. Roder, and W. M. Rogers (1957).
P.R.H.-1, 2	American Smelting and Refining Co.; 99.999% pure. #1: RRR = 1530. #2: RRR = 110.	#1: swaged, annealed in vacuum for 2 hrs. at 400°C, drawn, cleaned in acids, annealed in vacuum for 2 hrs. at 400°C. #2: swaged, cleaned in acids, annealed in vacuum for 2 hrs. at 400°C, drawn.	A-1; B-1; C-1; D-1(8); E-1; F-2; G-1; L-1, 2, 4, 9; M-2, 3; N-1; S-1, 2, 5.	R. L. Powell, H. M. Roder, and W. J. Hall (1959).

COPPER (cont'd)

(See FIGURES 19a–19c ; also 43a-43c and 43e)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
W. T.	American Smelting and Refining Co.; < 2 ppm Te and As; < 1 ppm Fe, Sb, and Se; RRR(21) = 2000.	Rolled and drawn, annealed in vacuum for some hours at 530°C.	A-1; B-1; C-1; D-4(2); E-1, 5; F-4; G-1; L-1, 2; M-1; S-1, 5.	G. K. White and R. J. Tainsh (1960).
See FIGURE 71	. . . . .	Measured below 1 K.	. . . . .	G. Davey and K. Mendelssohn (1963).
G. H.-1, 2, 3, 4, 5, 6	. . . . .	Electrolytic copper. Specimens were drawn at 0.0, 7.8, 14.0, 19.9, 25.4, and 30.8%, at low temperatures, for curves #1-#6 respectively.	A-1; B-1; C-1; D-2(2); F-4; G-2; L-1; M-1, 3; S-1, 5.	C. Gladun and W. Holzhäuser (1964).
See FIGURE 71	. . . . .	Measured below 1 K.	. . . . .	A. Dupré, A. van Itterbeek, and L. Michiels (1964).
. . . . .	. . . . .	Results within 2% of M. McE. G. curve between 93 and 273 K.	. . . . .	B. L. Rhodes, C. E. Moeller, and H. J. Sauer (1965).
See FIGURES 43e and 71	. . . . .	See results under Commercial Coppers and Copper Alloys; also measured below 1 K.	. . . . .	M. H. Jericho (1965).
See FIGURES 43e and 71	. . . . .	See results under Commercial Coppers and Copper Alloys; also measured below 1 K.	. . . . .	P. Lindenfeld, E. A. Lynton, and R. Soulen (1965).
M. McE. G.	American Smelting and Refining Co.; 99.999% pure; RRR = 900.	Free of voids and inclusions; average grain size of 574μ; average diamond pyramid hardness of 40 (with a load of 0.100 kg).	A-1; B-1; C-1; D-1(2); E-2; F-1; G-2; L-1, 2; P-1; S-1, 2, 5.	J. P. Moore, D. L. McElroy, and R. S. Graves (1967).
. . . . .	. . . . .	Graph of intrinsic thermal resistivity of 3 specimens.	. . . . .	J. T. Schriempf (1968).
B. Z. S.-1, 2, 3, 4	99.99% pure.	Specimens were unirradiated and irradiated with 1.6, 4.3, and 6.5×10^{19} neutrons/cm^2 at 54°C for curves #1-#4 respectively.	A-1; B-1; C-1; D-3(2); G-3; L-1; M-2.	H. F. Bowman, T. O. Ziebold, and J. L. Smith, Jr. (1969).


SILVER
FIGURE 20a
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
F.R.W.-2
F.R.W.-1
W.-4
W.-2
W.-5
R.
W.-3
M.R.
L.
W.-1
200
100
80
60
40
20
10
8
6
4
2
1
.8
.6
.4
.3
.2
4
6
8
10
20
40
60
80
100
200
300


SILVER
GOLD
FIGURE 20b
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
200
100
80
60
40
30
20
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
1
2
3
4
5
6
7
8
9
10
W.-2-Ag
F.R.W.-2-Ag
F.R.W.-1-Ag
W.-4-Ag
W.-5-Ag
W.-4-Au
R.-Ag
G.R.-Au
W.-5-Au
M.R.-Au
W.-2-Au
W.-3-Au
W.-3-Ag
M.R.-Ag
W.-1-Au
W.-1-Ag

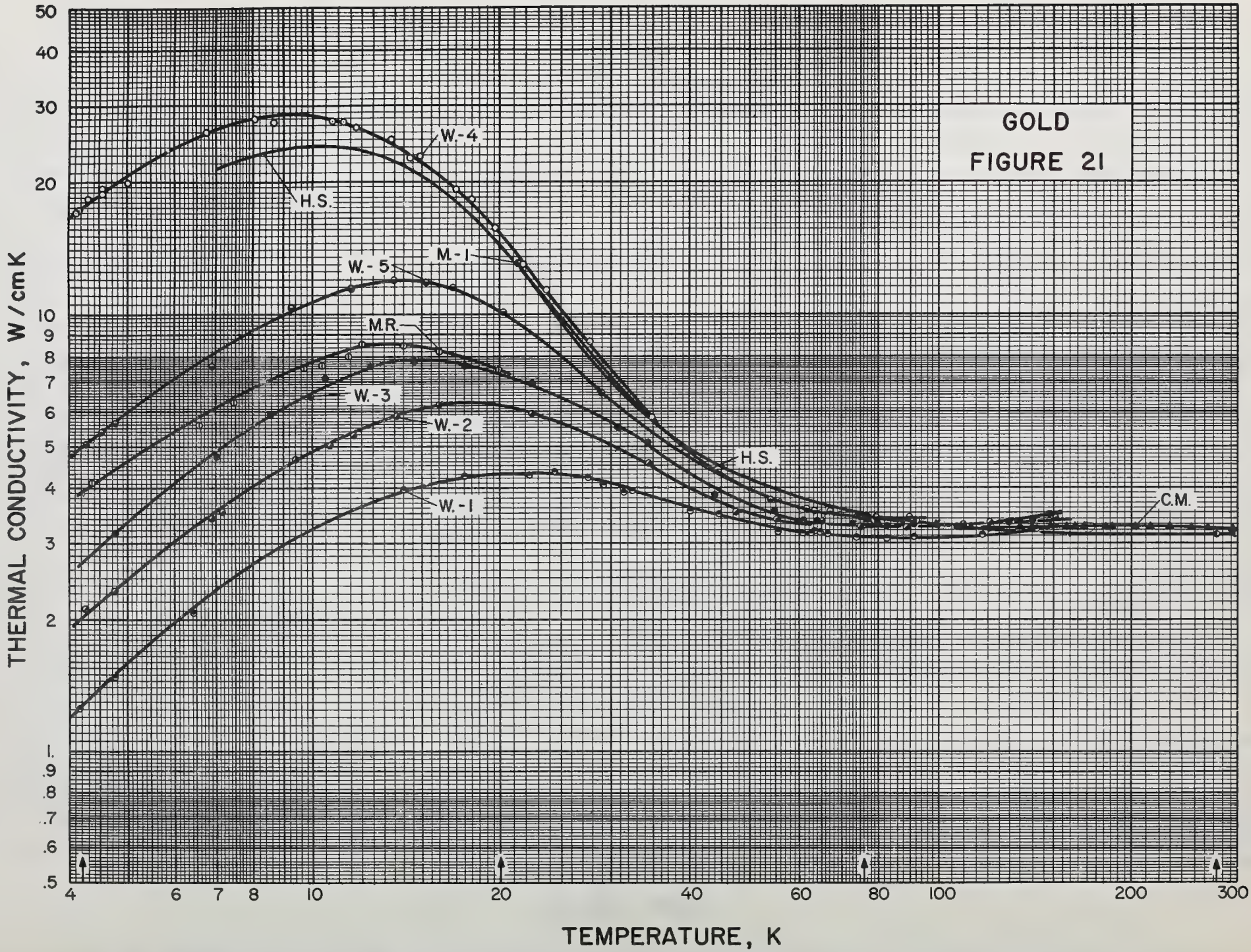
SILVER

(See FIGURES 20a and 20b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	Gold-und Silberscheideanstalt; 99.98% pure.	k = 4.14 at 18°C.	A-4; B-1; C-2, 3; D-1(3); E-1; F-4; G-3; S-1, 2, 3, 5.	W. Jaeger and H. Diesselhorst (1900).
L.	Johnson, Matthey; 99.9% pure.	Fine silver. Lathe-turned from a larger rod. Specific density of 10.47 at 21°C.	A-1; B-1; C-1; D-2(2); E-2; F-4; G-3; L-1; S-1, 5.	C. H. Lees (1908).
. . . . .	Heraeus.	k = 4.08 at 25°C.	A-4; B-1; C-3; G-2; M-2; S-1, 5.	F. A. Schulze (1911).
. . . . .	. . . . .	See Silver alloys.	. . . . .	E. Sedström (1919)
. . . . .	Commercially pure electrolytic silver; also spectroscopically pure silver, less pure than the first due to contamination during drawing.	Two silver wires had k = 4.11 and k = 4.04 at at 0°C, respectively.	A-4; B-5; C-3; E-8; F-5; G-3; S-1, 5.	W. G. Kannuluik (1931).
. . . . .	Hilger; trace of Bi, Ca, Cu, Mg, Na, Pb, Si.	At 90, 195, and 273 K values are about 2% greater than Lees (1908).	A-4; B-5; C-3; E-8; F-5; G-3; L-1; S-1, 5.	W. G. Kannuluik (1933).
. . . . .	. . . . .	Five rods of silver, varied in composition, annealing, and crystal structure. At 20 and 90 K pure rods had values close to curve W.-3.	. . . . .	E. Grüneisen and H. Reddemann (1934).
. . . . .	Hönigschmid.	Annealed; electrolytic; k = 31.4 at 21 K; measured in transverse magnetic field up to 1.22 T. Graph of field dependence.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-3; L-1; M-1; N-2, 4; P-1; S-1, 5.	E. Grüneisen and H. Adenstedt (1938).
M.R.	Johnson, Matthey 1722; 99.99% pure; RRR(20) = 30.9.	. . . . .	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1.	K. Mendelssohn and H. M. Rosenberg (1952a).
. . . . .	Two specimens.	Measured in transverse and longitudinal magnetic fields up to 0.4 T. Graph of field dependence.	. . . . .	K. Mendelssohn and H. M. Rosenberg (1953).

SILVER (cont'd)
(See FIGURES 20a and 20b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
W.-1, 2, 3, 4, 5	Johnson, Matthey 4606.	#1: as supplied. #2: annealed at 650°C, grain size of 0.1 mm. #3: cold-drawn from #2. #4: annealed at 650°C. #5: specimen #4 re-measured after reinsertion in apparatus. Graph of intrinsic thermal resistivity.	A-1; B-1; C-1; D-4(2); E-1, 5; F-4; G-1; L-1, 2; M-1; N-1.	G. K. White (1953b).
R.	Johnson, Matthey 3351; "considerably purer" than M.R. specimen above.	Drawn, annealed in vacuum for several hours at 750°C. Review of M.R. above, also.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1; S-1, 5.	H. M. Rosenberg (1955).
. . . . .	. . . . .	See SILVER ALLOYS Tables and Figures for results on dilute silver alloys.	. . . . .	A. N. Gerritsen and J. O. Linde (1956).
F.R.W.-1, 2	Engelhard.	Rolled, then drawn; annealed in vacuum for 3 hrs. at 850°C. Coefficients of intrinsic thermal resistivity.	A-1; B-1; C-1; D-4(2); E-1, 5; F-4; G-1; L-1, 2; M-1.	E. W. Fenton, J. S. Rogers, and S. B. Woods (1963).
See FIGURE 71	. . . . .	Measured below 1 K.	. . . . .	K. Mendelssohn, J. K. N. Sharma, and I. Yoshida (1965).
. . . . .	. . . . .	Graph of intrinsic thermal resistivity for two specimens.	. . . . .	C. Van Baarle, G. J. Roest, K. K. Roest-Young, and F. W. Gorter (1966)
See FIGURE 71	. . . . .	Measured below 1 K.	. . . . .	J. K. N. Sharma (1967).


GOLD
FIGURE 21
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
W.-4
H.S.
M.-1
W.-5
M.R.
W.-3
W.-2
W.-1
H.S.
C.M.
50
40
30
20
10
9
8
7
6
5
4
3
2
1
.9
.8
.7
.6
.5
4
6
7
8
10
20
40
60
80
100
200
300

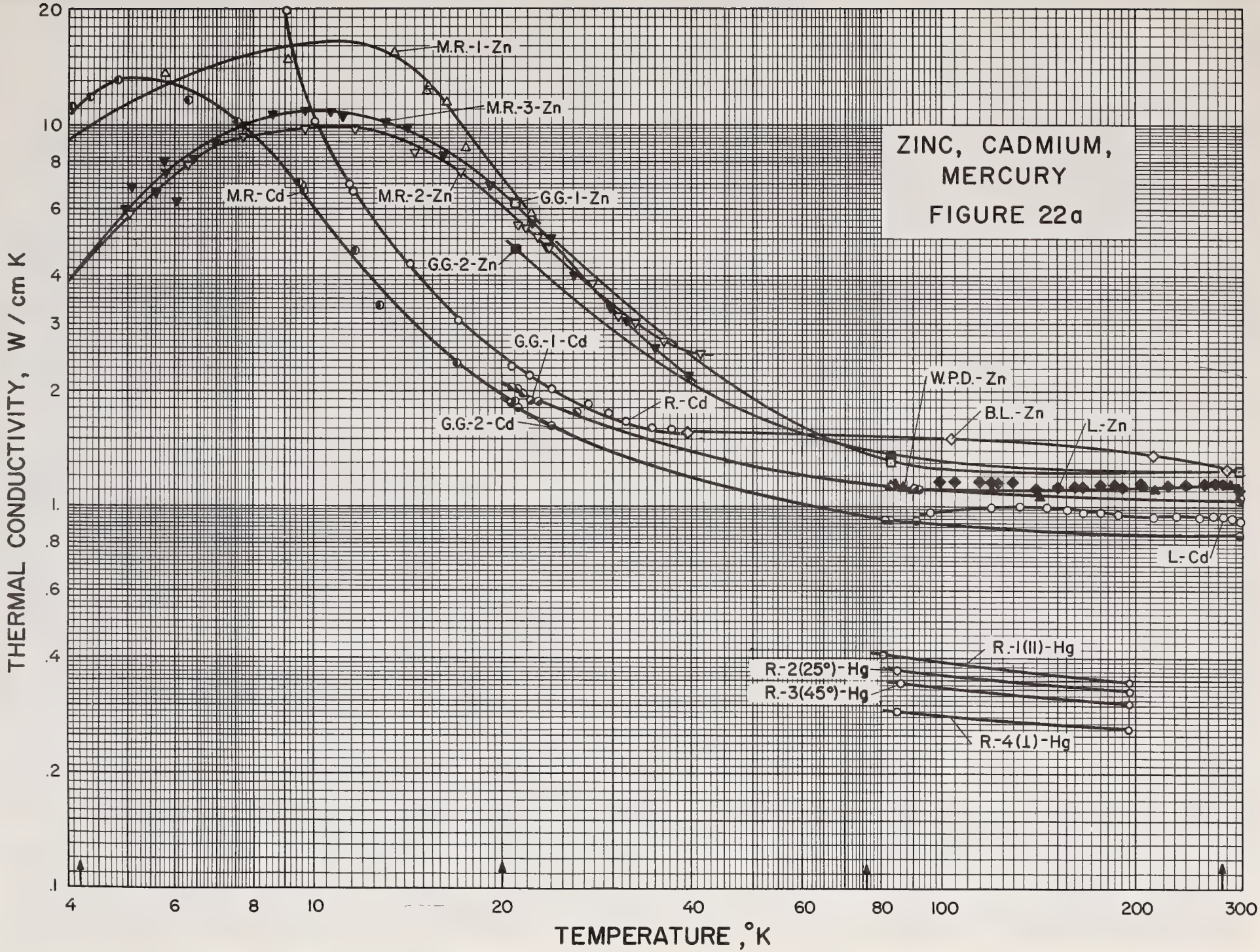
GOLD
(See FIGURES 20b and 21)

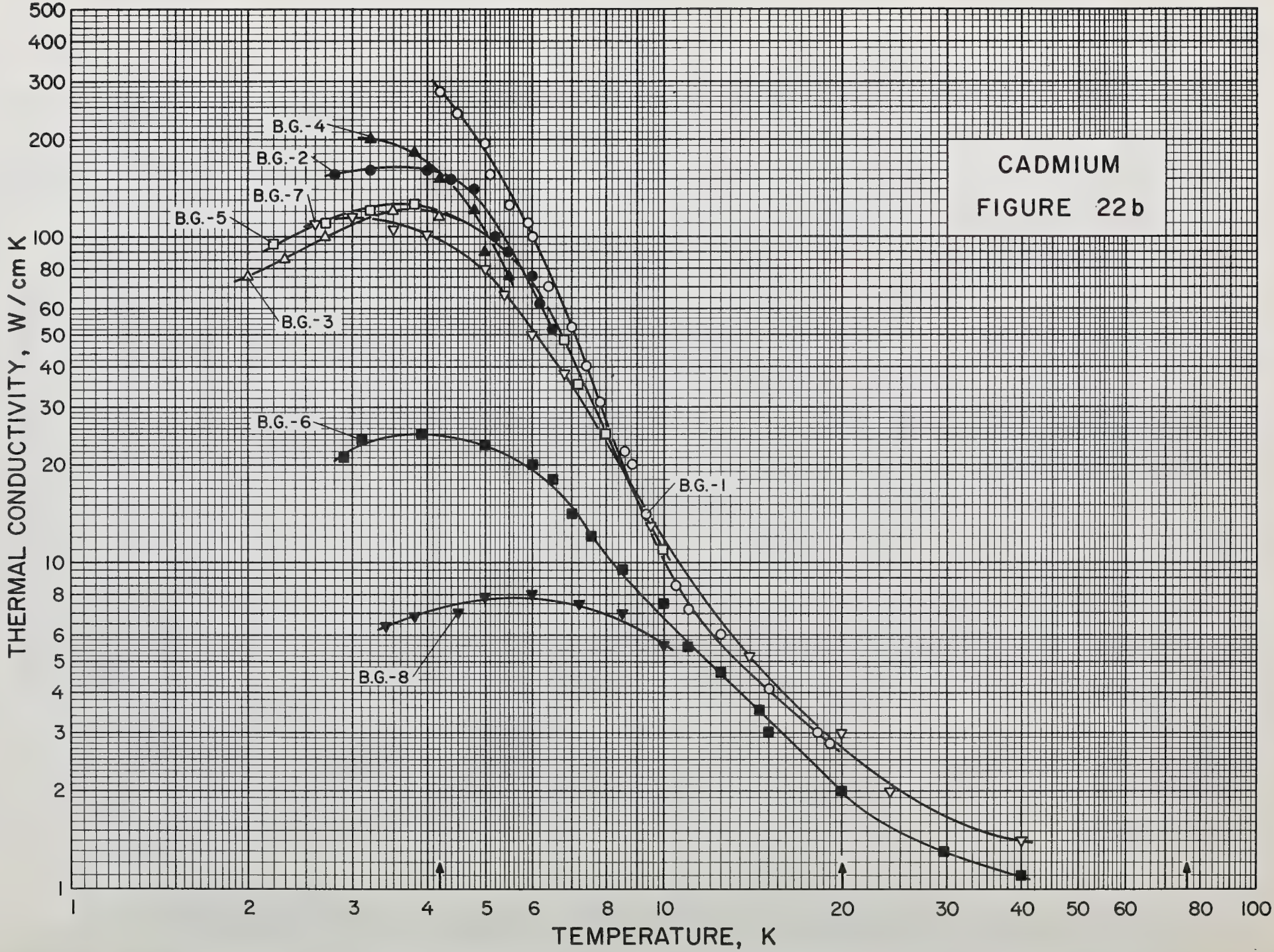
CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	#1: Sy & Wagner; "pure". #2: Goldscheide Anstalt; "impure".	#1: k = 2.93 at 18°C; #2: k = 1.79 at 18°C.	A-4; B-1; C-2, 3; D-1(3); E-1; F-4; G-3; S-1, 2, 3, 5.	W. Jaeger and H. Diesselhorst (1900).
. . . . .	Heraeus.	k = 3.18 at 25°C.	A-4; B-1; C-3; G-2; M-2; S-1, 5.	F. A. Schulze (1911).
. . . . .	. . . . .	k = 2.95 at 17°C; specific density of 19.49.	A-5; B-1; C-1; D-2(2); E-2; F-5; G-3; S-1.	T. Barratt (1914).
M.	Mylius; 99.999% pure.	Cold-drawn; annealed.	A-4; B-1; C-3; D-2(2); E-5; F-4; G-2; L-1; M-1; P-1; S-1, 2, 4, 5.	W. Meissner (1915).
. . . . .	. . . . .	. . . . .	. . . . .	E. Sedström (1924).
. . . . .	. . . . .	Approximately the same as Barratt (1914) at 24°C.	. . . . .	H. Masumoto (1927).
. . . . .	. . . . .	Six specimens of various composition and annealing. Results for "very pure" gold at 21 and 83 K fall close to curve W.-4.	. . . . .	E. Grüneisen and E. Goens (1927).
. . . . .	Heraeus; "pure".	Approximately the same as Jaeger and Diesselhorst (1900) at 18°C.	. . . . .	C. H. Johansson and J. O. Linde (1930).
. . . . .	Heraeus; 99.99% pure.	k = 3.06 at 0°C.	A-4; B-5; C-3; E-8; F-5; G-3; S-1, 5.	W. G. Kannuluik (1931).
M.R.	Johnson, Matthey 1916a; 99.999% pure.	. . . . .	A-1; B-5; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1.	K. Mendelssohn and H. M. Rosenberg (1952a).

GOLD (cont'd)

(See FIGURES 20b and 21)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
W.-1, 2, 3, 4, 5	#1 and #2: Garrett, Davidson, and Matthey; 99.9% pure; Ag; trace of Pt; faint traces of Cu, Fe, Pb, Sn. #3, #4, and #5: Johnson, Matthey 3226; > 99.999% pure; spectrographic lines of Ag and Cu; faint lines of Cd, Fe, Mg, and Na; very faint lines of Ca and Zn.	#1: as received. #2: specimen #1 annealed in vacuum for about 3 hrs. at 700°C and cooled slowly to 200°C for 6 hrs. #3: cold-drawn. #4: specimen #3 annealed in vacuum for about 3 hrs. at 700°C and cooled slowly to 200°C for 6 hrs. #5: specimen #4 reduced by cold-drawing. Graph of intrinsic thermal resistivity.	A-1; B-1; C-1; D-4(2); E-1, 5; F-4; G-1; L-1, 2; M-1; N-1.	G. K. White (1953a).
. . . . .	Same as M.R. RRR(20) = 51.8.	Review of M.R. paper above.	. . . . .	H. M. Rosenberg (1955).
See FIGURE 71	. . . . .	Measured below 1 K.	. . . . .	G. Davey and K. Mendelssohn (1963).
See FIGURE 71	. . . . .	Measured below 1 K.	. . . . .	K. Mendelssohn, J. K. N. Sharma, and I. Yoshida (1965).
See FIGURE 71	. . . . .	Measured below 1 K.	. . . . .	J. K. N. Sharma (1967 a).
G.M.	Cominco; 99.999% pure; RRR = 92.5	Annealed in air for 2 hrs. at 600°C. Table of lattice, electronic, and intrinsic thermal conductivity.	A-1; B-1; C-1; D-1(2); E-3; F-1; G-1; L-1, 2, 5; M-1; S-1, 5.	J. G. Cook and M. P. van der Meer (1970).
G.R.-Au	99.999% pure; traces of Cu, Ag, Si, and Pb; RRR = 536.	Annealed in vacuum for 36 hours at 600°C. Graph of Lorenz ratio. See also Gold Alloys.	A-1; B-1; C-1; D-3(2); E-5; G-2; L-1, 2; M-2; S-1, 5.	P. L. Garbarino and C. A. Reynolds (1971).
H.S.	AGARD(Advisory Group for Aerospace Research and Development); 99.999% pure; density of 19.28 ± 0.01 g/cm^3; DP hardness 29.2; grain size 0.013 mm; RRR = 289 ± 6.	Specimen swaged twice from received-size of 4.0 mm to final size of 1.9 mm; then annealed 2 hrs. at 673 K, furnace-cooled to room temperature. Specimen also measured twice, after each swaging, with measurements 25% above the maximum of curve W-5, and 18% above the maximum of curve W-2 respectively.	A-1; B-1; C-1; D-1(8); E-1, 2, 3; F-1; G-1; L-1, 2; M-1; S-1, 2, 5.	J. G. Hust and L. L. Sparks (1971a).


ZINC, CADMIUM, MERCURY
FIGURE 22a
THERMAL CONDUCTIVITY, W / cm K
TEMPERATURE, °K
M.R.-1-Zn
M.R.-3-Zn
M.R.-Cd
M.R.-2-Zn
G.G.-1-Zn
G.G.-2-Zn
G.G.-1-Cd
G.G.-2-Cd
R.-Cd
W.P.D.-Zn
B.L.-Zn
L.-Zn
L.-Cd
R.-1(II)-Hg
R.-2(25°)-Hg
R.-3(45°)-Hg
R.-4(⊥)-Hg
20
10
8
6
4
3
2
1.
.8
.6
.4
.2
.1
4
6
8
10
20
40
60
80
100
200
300


CADMIUM
FIGURE 22b
B.G.-4
B.G.-2
B.G.-7
B.G.-5
B.G.-3
B.G.-6
B.G.-1
B.G.-8
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
500
400
300
200
100
80
60
50
40
30
20
10
8
6
5
4
3
2
1
1
2
3
4
5
6
8
10
20
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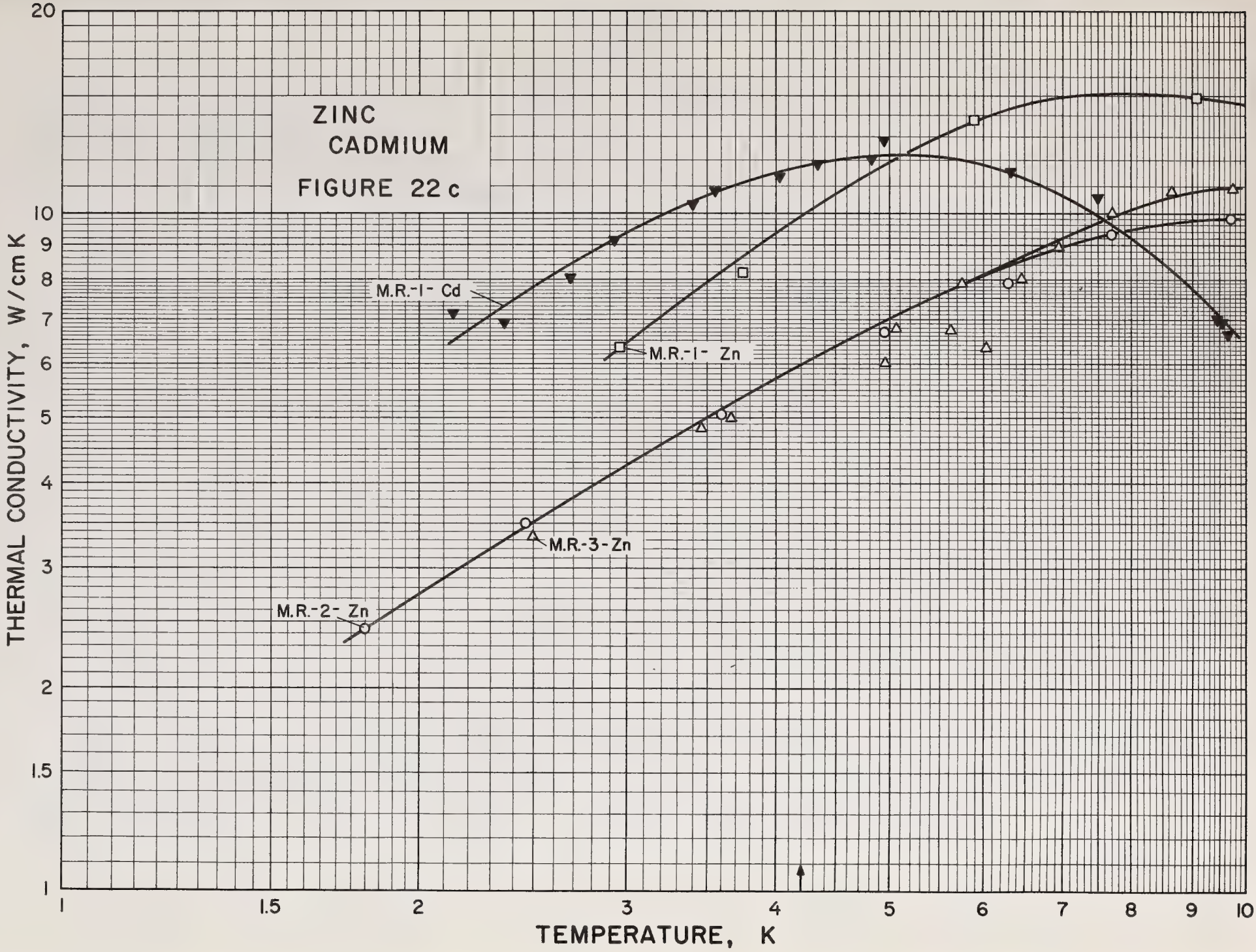
40
50
60
80
100


ZINC
CADMIUM
FIGURE 22 c
M.R.-1- Cd
M.R.-1- Zn
M.R.-3-Zn
M.R.-2- Zn
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
20
10
9
8
7
6
5
4
3
2
1.5
1
1
1.5
2
3
4
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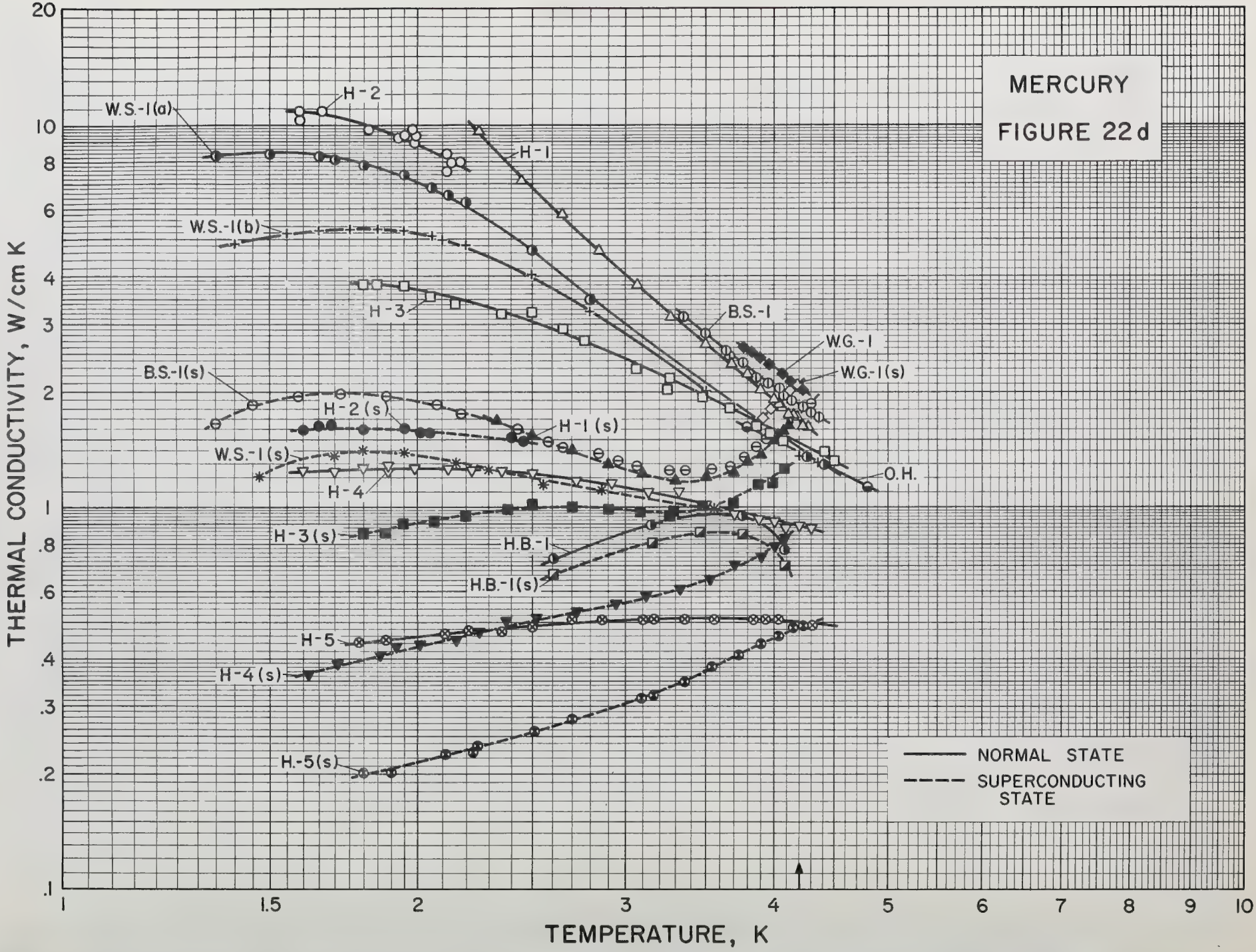
6
7
8
9
10


MERCURY
FIGURE 22d
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
20
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
1
1.5
2
3
4
5
6
7
8
9
10
W.S.-1(a)
H-2
H-1
W.S.-1(b)
H-3
B.S.-1
W.G.-1
W.G.-1(s)
B.S.-1(s)
H-2(s)
H-1(s)
W.S.-1(s)
H-4
O.H.
H-3(s)
H.B.-1
H.B.-1(s)
H-5
H-4(s)
H.-5(s)
NORMAL STATE
SUPERCONDUCTING STATE

ZINC

(See FIGURES 22a and 22c)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	Kahlbaum; "pure"; 0.01% Cd, Fe, Pb.	Cast. k = 1.1 at 18°C. Specific density of 7.11.	A-4; B-1; C-2, 3; D-1(3); E-1; F-4; G-3; S-1, 2, 3, 5.	W. Jaeger and H. Diesselhorst (1900).
L.-Zn	"Pure redistilled".	Lathe-turned from a cast stick. Specific density of 7.10.	A-1; B-1; C-1; D-2(2); E-2; F-4; G-3; L-1; S-1, 5.	C. H. Lees (1908).
. . . . .	. . . . .	Measured effect of pressure on thermal conductivity at 25°C from 1 atmosphere to 2,500 atmospheres.	. . . . .	S. Lussana (1918).
B.L.-Zn	National Bureau of Standards; 99.993% pure; 0.005% Fe; 0.0018% Cd.	Single crystal prepared by Bridgmann technique in glass mold in vacuum. Basal planes parallel to axis of rod. Also measured polycrystalline specimens.	A-5; B-1; C-1; D-1(6); E-8; F-5; G-3; L-1.	C. C. Bidwell and E. J. Lewis (1929); also C. C. Bidwell (1928).
. . . . .	Kahlbaum; "pure".	k = 1.26 at 83 K; k = 1.25 at 273 K.	A-6; B-1; C-1; D-1(2); E-2; F-4; G-3; S-1, 5.	J. Staebler (1929).
G.G.-1, 2-Zn	Kahlbaum; "pure". #1: RRR = 120. #2: RRR = 115.	Single crystals; drawn from the melt. #1: rod axis inclined 8.7° from hexagonal axis. #2: rod axis inclined 79.7° from hexagonal axis. A crystal of inclination 4.9°(RRR = 114) had thermal conductivity values 3% lower at 20°C. Another of inclination 3.6°(RRR = 93) had values 16% lower at 20°C.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-3; L-1; N-4; S-1, 5.	E. Goens and E. Grüneisen (1932).
. . . . .	. . . . .	Verifies previous work by Bidwell and Lewis (1929) at -37°C.	. . . . .	C. C. Bidwell (1939).
M.R.-1, 2, 3	#1: Hilger 8392; 99.9995% pure. #2 and #3: Imperial Smelting Corp.; 99.997% pure.	#1: polycrystalline. #2: single crystal; rod axis inclined 80° to hexagonal crystal axis. #3: single crystal; rod axis inclined 13° to rod axis.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1; N-4.	K. Mendelssohn and H. M. Rosenberg (1952a); see also Rosenberg (1957).
. . . . .	. . . . .	Measured effects of transverse and longitudinal magnetic fields up to 0.4 T. Graph of field dependence.	. . . . .	K. Mendelssohn and H. M. Rosenberg (1953).

ZINC (cont'd)

(See FIGURES 22a and 22c)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	Review of M.R.-2, 3 above.	. . . . .	H.M. Rosenberg (1955).
. . . . .	. . . . .	Measured the change in thermal resistivity in fields up to 0.08 T in the normal, intermediate, superconducting states. Graphs of field dependence.	. . . . .	P.B. Alers, D.A. Spohr, and R.T. Webber (1955).
See FIGURE 72	. . . . .	Measured both normal and superconducting states below 1 K.	. . . . .	N.V. Zavaritskii (1958).
See FIGURE 72	. . . . .	Measured the superconducting state below 1 K.	. . . . .	N.V. Zavaritskii (1961).
W.P.D.-Zn	American Smelting and Refining; 99.999% pure.	Turned from a casting.	A-1; B-1; C-1; D-1(3); E-2; F-4; G-3; S-1.	K.E. Wilkes, R.W. Powell, and D.P. DeWitt (1969).

CADMIUM
(See FIGURES 22a — 22c)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	"Pure".	k = 0.92 at 0°C.	A-5; B-1; C-1; D-7(9); F-5; G-3; S-1, 3, 5.	L. Lorenz (1881).
. . . . .	Kahlbaum; "pure"; traces of Fe, Pb, and Zn (< 0.05%).	Cast. k = 0.93 at 18°C. Specific density of 8.63.	A-4; B-1; C-2, 3; D-1(3); E-1; F-4; G-3; S-1, 2, 3, 5.	W. Jaeger and H. Diesselhorst (1900).
L.-Cd	"Pure redistilled".	Lathe turned from a cast stick. Specific density of 8.64 at 21°C.	A-1; B-1; C-1; D-2(2); E-2; F-4; G-3; L-1; S-1, 5.	C. H. Lees (1908).
. . . . .	Kahlbaum; "pure".	Melted under H_2 atmosphere; cast. k = 1.02 at 273 K; k = 1.02 at 194 K; k = 1.23 at 83 K.	A-1; B-1; C-1; D-1(2); F-4; G-3; L-1; M-2; S-1, 2, 5.	A. Eucken and G. Gehlhoff (1912).
. . . . .	Kahlbaum; "chemically pure".	Results at 21, 89, and 273 K about 5% lower than G. G.-1-Cd.	A-1; B-1; C-1; D-1(2); E-1; F-5; G-3; L-1; M-1; S-1, 5.	R. Schott (1916).
. . . . .	. . . . .	Measured effect of pressure on thermal conductivity at 25°C from 1 atmosphere to 3,000 atmospheres.	. . . . .	S. Lussana (1918).
G. G.-1, 2-Cd	Kahlbaum; "pure". #1: RRR = 46. #2: RRR = 52.	Single crystals; drawn from the melt. #1: rod axis inclined 14° from hexagonal axis. #2: rod axis inclined 84° from hexagonal axis.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-3; L-1; N-4; S-1, 5.	E. Goens and E. Grüneisen (1932).
. . . . .	. . . . .	Measured effect of transverse and longitudinal magnetic fields up to 0.39 T. Graph of field dependence.	. . . . .	K. Mendelssohn and H. M. Rosenberg (1951; 1953).
M. R.-Cd	Hilger 10547; 99.9999% pure; RRR = 50.4	Cast in glass. Same specimen as one of the specimens Mendelssohn and Rosenberg (1951; 1953).	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1.	K. Mendelssohn and H. M. Rosenberg (1952a).
R.-Cd	Hilger 8670; 99.995% pure.	Single crystal; rod axis inclined 79° from hexagonal axis. Measured values at lower temperatures: k = 22 at 8.8 K; k = 36 at 6.2 K; k = 38 at 6.5 K; k = 69 at 5.3 K; k = 89 at 4.7 K; k = 61.5 at 1.6 K; k = 60 at 1.5 K. Also, review of M. R.-Cd.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1, 2; S-1, 5.	H. M. Rosenberg (1955); see also Rosenberg (1957).

CADMIUM (cont'd)
(See FIGURES 22a — 22c)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
See FIGURE 72	. . . . .	Measured in the superconducting state below 1 K.	. . . . .	N. V. Zavaritskii (1961).
See FIGURE 72	. . . . .	Measured both the normal and superconducting states below 1 K.	. . . . .	J. K. N. Sharma (1967a).
B. G. -1, 2, 3, 4, 5, 6, 7, 8	Harshaw; 7 ppm(wt) Ca, < 5 Sn and Ta, 4 Cℓ, 3 C and Li, < 3 In, 2 K, N_2, and O_2, < 2 Au and Te, < 1 Ag, Ba, Cr, Th, Ti, Tℓ, and W. #1-#4: RRR(20) = 5 x 10^4. #5: 0.011 (atomic) Zn; RRR(20) = 1.8 x 10^4. #6: 0.084 Zn; RRR(20) = 3100. #7: 0.011 Zn; RRR(20) = 1.9 x 10^4. #8: 0.56 Zn; RRR(20) = 570.	Single crystals; specimens cut in plane with spark cutter, etching off 0.1 mm; zinc impurities diffused into crystal at 200°C for 4-7 days; homogenized at 200°C for 7 days. Typical dimensions of 1.5 x 1.5 mm x 2.5 cm. #1: width 1.9 mm, rod axis parallel to c-axis. #2: width 0.7 mm, rod axis parallel to c-axis. #3: width 0.45 mm, rod axis parallel to c-axis. #4: width 2.15 mm, rod axis perpendicular to c-axis. #5: width 1.03 mm, rod axis parallel to c-axis. #6: width 1.13 mm, rod axis parallel to c-axis. #7: width 1.12 mm, rod axis perpendicular to c-axis. #8: width 1.00 mm, rod axis perpendicular to c-axis.	A-1; B-1; C-1; D-3(2); E-3; F-4; G-2; L-1, 2, 3, 4, 5, 9; M-2; N-1, 7, 8; S-5.	R. Bogaard and A. N. Gerritsen (1971).

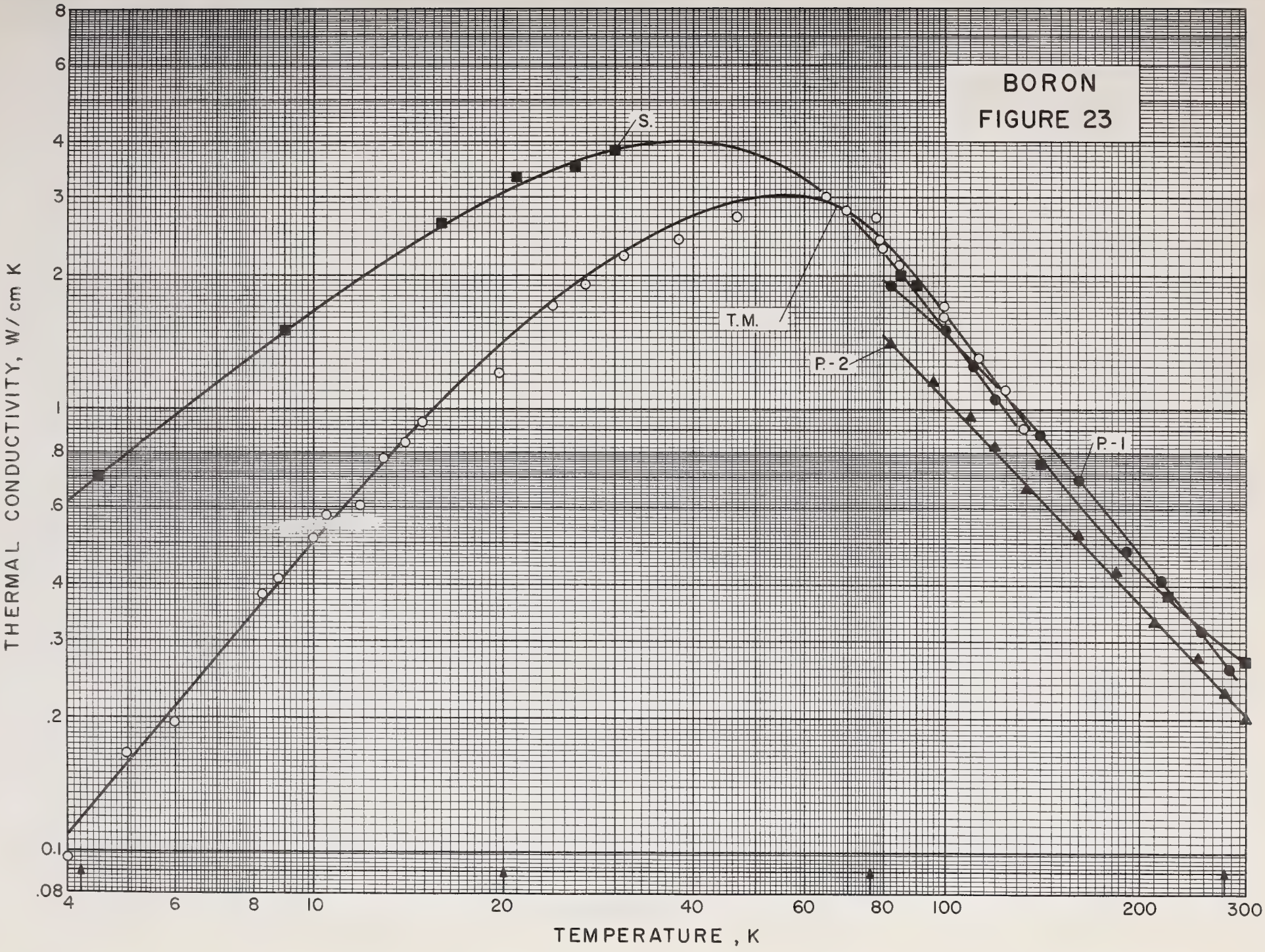
MERCURY

(See FIGURES 22a and 22d)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
O.H.	. . . . .	Transition temperature of 4.19 K.	A-1; B-3; C-1; D-1; F-5; G-3; M-1; N-3; S-1, 2, 3.	H.K. Onnes and G. Holst (1914).
. . . . .	. . . . .	Measured in the liquid state and in solid state near melting.	. . . . .	G. Gehlhoff and F. Neumeier (1919).
R.-1(∥), 2(25°), 3(45°), 4(⊥)-Hg	. . . . .	Measured ten single crystal rods, crystallized in a glass tube, which fall into four groups. #1(∥): rod axis inclined 0-8° to crystal axis. #2(25°): axes inclined 21-28°. #3(45°): axes inclined 38-46°. #4(⊥): axes inclined 90°.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-3; L-1; N-4; S-1, 2, 5.	H. Reddemann (1932).
H.B.-1, 1(s)	. . . . .	Crystallized in a glass U-tube. Specimen measured in the normal (in a field of 0.04 T) and superconducting (s) states.	A-1; B-3; C-1; D-2(2); E-2,5; F-4; G-2; L-1; M-1; N-3.	W.J. de Haas and H. Bremmer (1936).
H.-1, 1(s), 2, 2(s), 3, 3(s), 4, 4(s), 5, 5(s)	Johnson, Matthey 3100. #1: pure. #2: 0.002% Cd. #3: 0.007% Cd. #4: 0.10% In. #5: 0.39% In (weight percent).	Homogeneous solid solutions cast in Ge-Ag tubes; polycrystalline, large crystals. Measured in both normal (in a longitudinal magnetic field up to 0.15 T) and superconducting (s) states.	A-1; B-1; C-1; D-4(2); E-5; F-4; G-2; L-1, 2; M-1; N-3; P-2, 4; Q-1.	J.K. Hulm (1950).
. . . . .	. . . . .	Measured in the intermediate state near 4 K. Graph of magnetic field dependence.	. . . . .	R.T. Webber and D.A. Spohr (1953); see also P.B. Alers, D.A. Spohr, and R.T. Webber (1955).
W.S.-1(a), 1(b), 1(s)	Eimer and Amend CP reagent M-141; 99.9% pure; 0.05% Ag and Cu; trace of other base elements.	Cast in 90/10 cupronickel. Randomly oriented grains. Measured in the normal, (in a transverse magnetic field of -#1(a): 0.0491 T and #1(b): 0.0859 T) and superconducting (s) states. Also measured in a transverse magnetic field of 0.0737 T. Graph of magnetic field, both transverse and longitudinal, dependence up to .12 T in normal and intermediate state.	A-1; B-1; C-1; D-3(2); E-4,5; F-4; G-2; L-1, 2; M-1; N-2, 3.	R.T. Webber and D.A. Spohr (1957).

MERCURY (cont'd)
(See FIGURES 22a and 22d)

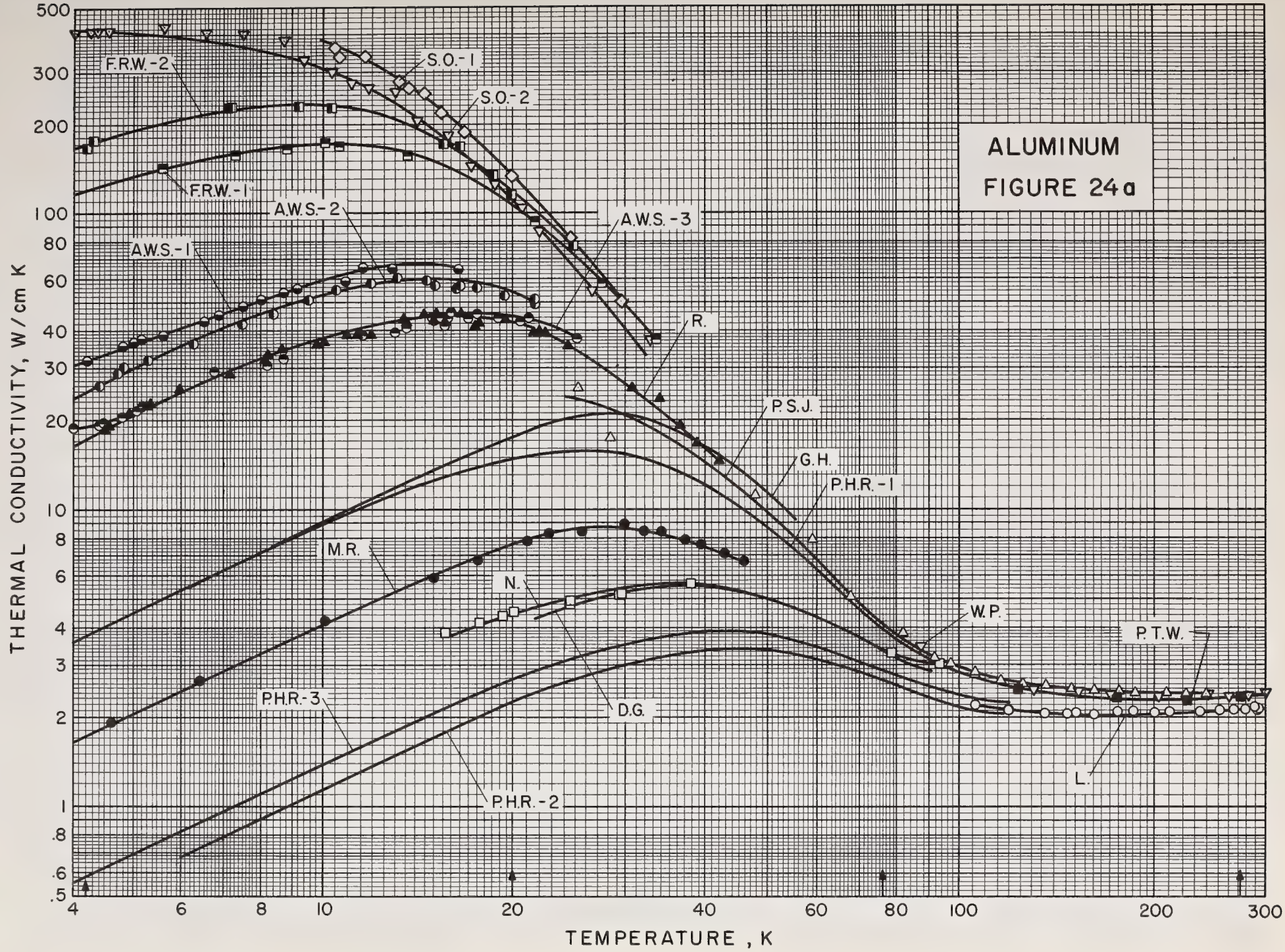
CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
W.G.-1,1(s)	Johnson, Matthey.	Triply distilled. Cast in a paper tube. Measured in both the normal (in longitudinal fields up to 0.085 T) and superconducting (s) states.	A-1; B-1; C-1; D-3(2); E-5; F-5; G-3; L-1; M-1; N-3.	J.H.P. Watson and G.M. Graham (1963).
B.S.-1,1(s)	United Mineral and Chemical Corp.; 99.99999% pure.	Cast is stainless steel. Thirty runs on different crystals. Measured in both the normal (in a longitudinal magnetic field of 0.04 T) and superconducting (s) states. Thermal conductivity values at the transition temperature varied from 1.4 to 1.9, probably caused by uncontrolled and undetermined crystal orientation.	A-1; B-1; C-1; D-3(4); E-5; F-4; G-2; L-1,2,3,5,8; N-3.	S.M. Bhagat and A.T. Serlemitsos (1969).

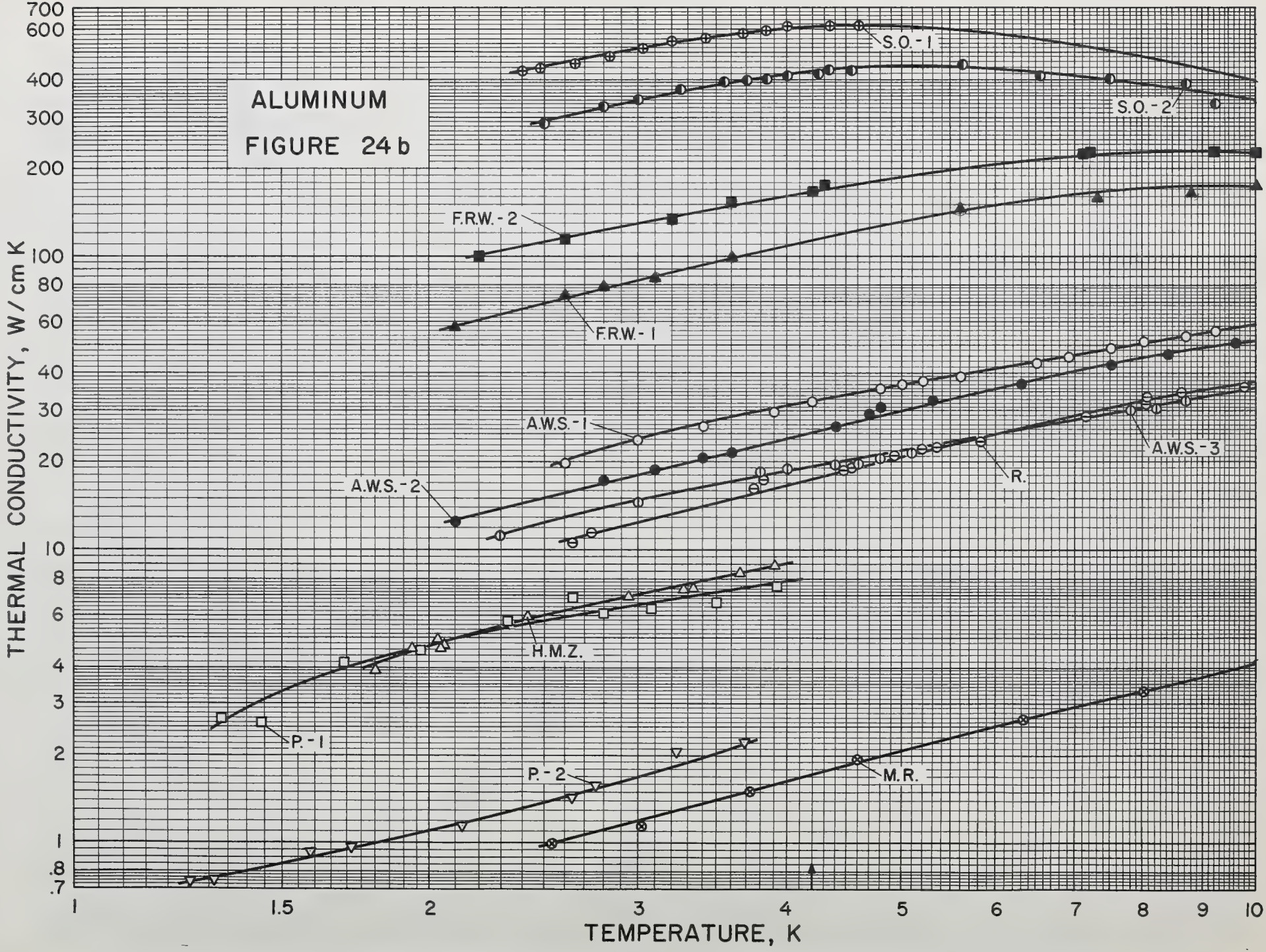

BORON
FIGURE 23
S.
T.M.
P.-2
P.-1
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
8
6
4
3
2
1
.8
.6
.4
.3
.2
0.1
.08
4
6
8
10
20
40
60
80
100
200
300

BORON

(See FIGURE 23)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
T.M.	Texaco Experiment, Inc.; 0.1% C.	Single crystal of the β-rhombohedral phase; semiconductor. Grown by float-zone method. Density of 2.342 g/cm^3.	A-1; B-1; C-1; D-1(2); F-4; G-2; O-3; P-2, 3, 5, 8.	J.C. Thompson and W.J. McDonald (1963).
S.	Eagle-Picher M 6005 CP; 0.8 Si; 0.3 Aℓ; < 0.3 Ti; 0.04 Cu (units of 10^{18} atoms/cm^3).	β-rhombohedral; grown from the melt by floating zone process. Columner crystallites of 0.1 cm diameter and 2 cm length. Electrical resistivity > 10^3Ω-cm. Another specimen of less purity had the same values within experimental error. Both are semiconductors.	A-1; B-1; C-1; D-1(2); E-1, 4; F-4; G-2; P-5, 7, 8; S-1.	G.S. Slack (1965).
P.-1, 2	#1: < 0.01% Mg; < 0.001% Aℓ, Bi, Cu, Fe, and Si. #2: 0.37% C; 0.2% Fe; 0.01% Aℓ; 0.05% Si; < 0.001% Mg.	β-rhombohedral. #1: prepared by the zone-melting method. Electrical resistivity of 1.7 × 10^6Ω-cm at 300 K. #2: cut from ingot of fused boron. Electrical resistivity of 4.5 × 10^5Ω-cm at 300 K. Results of one other crystal are within 10% of #1; results of a fourth crystal are within 5% of #2.	G-3; O-1; P-7.	A.V. Petrov, M.S. Germaidze, O.A. Golikova, A. Yu. Kiskachi, and V. N. Matveev (1969).


ALUMINUM
FIGURE 24a
F.R.W.-2
F.R.W.-1
S.O.-1
S.O.-2
A.W.S.-1
A.W.S.-2
A.W.S.-3
R.
P.S.J.
G.H.
P.H.R.-1
M.R.
N.
W.P.
P.T.W.
D.G.
L.
P.H.R.-3
P.H.R.-2
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
500
300
200
100
80
60
40
30
20
10
8
6
4
3
2
1
.8
.6
.5
4
6
8
10
20
40
60
80
100
200
300


ALUMINUM
FIGURE 24 b
S.O. - 1
S.O. - 2
F.R.W. - 2
F.R.W. - 1
A.W.S. - 1
A.W.S. - 2
A.W.S. - 3
R.
H.M.Z.
P. - 1
P. - 2
M.R.
THERMAL CONDUCTIVITY, W / cm K
TEMPERATURE, K
700
600
400
300
200
100
80
60
40
30
20
10
8
6
4
3
2
1
.8
.7
1
1.5
2
3
4
5
6
7
8
9
10

ALUMINUM
(See FIGURES 24a and 24b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	k = 1.43 at 0°C.	A-5; B-1; C-1; D-7(9); F-5; G-3; S-1, 3, 5.	L. Lorenz (1881 a).
. . . . .	Basse & Selve; 0.48% Fe; 0.36% Cu.	Drawn. k = 2.01 at 18°C. Specific density of 2.71.	A-4; B-1; C-2, 3; D-1(3); E-1; F-4; G-3; S-1, 2, 3, 5.	W. Jaeger and H. Diesselhorst (1900).
L.	Johnson, Matthey; 99% pure.	Lathe turned from a rod. Specific density of 2.70 at 20°C.	A-1; B-1; C-1; D-2(2); E-2; F-4; G-3; L-1; S-1, 5.	C.H. Lees (1908).
. . . . .	Commercial.	k = 1.93 at 0°C; k = 1.90 at 84.8 K; k = 1.63 at 21.7 K; k = 1.55 at 20.7 K.	A-1; B-1; C-1; D-1(2); E-1; F-5; G-3; L-1; M-1; S-1, 5.	R. Schott (1916).
. . . . .	. . . . .	Measured the effect of torsion on the thermal and electrical conductivities, especially on single crystals.	. . . . .	J.E. Calthrop (1924).
. . . . .	5 specimens ranging from pure to technical.	Measured at 20 and 80 K; results for purest specimens lie 10-20% below curve P.S.J. Studied effect of grain size and crystal boundaries.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-3; L-1, 2; M-1; P-1; S-1, 5.	E. Grüneisen and E. Goens (1927); also E. Grüneisen (1927).
. . . . .	. . . . .	k = 2.26 at 0°C; k = 2.55 at 89 K.	A-6; B-1; C-1; D-1(2); E-2; F-4; G-3; S-1, 5.	J. Staebler (1929).
. . . . .	. . . . .	k = 2.26 at 0°C; k = 2.56 at 80 K.	A-1; B-1; C-1; D-1(2); E-2; F-4; G-3; S-1, 5.	W. Mannchen (1931).
. . . . .	. . . . .	Result at 0°C within 2% of P.T.W.	. . . . .	A. Eucken and H. Warrentrup (1935).
. . . . .	#1: 99.95% pure. #2: 99.2% pure; 0.67% Fe; 0.10% Si; 0.01% Cu; < 0.01% Mg and Mn.	#1: k = 2.25 at 25°C. #2: k = 2.1 at 25°C.	A-5; B-1; C-1; D-1(6); E-8; F-3; G-3.	C.C. Bidwell and C. L. Hogan (1947).
N.	Hadfield.	As rolled. Brinell hardness of 17.	A-1; B-1; C-1; D-2(2); E-5; F-2; G-2; L-1; M-1.	J. deNobel (1951).

ALUMINUM (cont'd)
(See FIGURES 24a and 24b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
A.W.S.-1, 2, 3	#1: Alcoa; > 99.996% pure; 0.001% Mg and Si; 6 ppm Fe; 4 ppm Cu and Na; RRR = 840. #2: same as #1; RRR = 675. #3: Johnson, Matthey; > 99.995% pure; 0.002% Mg; < 0.001% Si; < 5 ppm Cu and Fe; faint trace of Na; RRR = 467.	#1 and #2: single crystals. #3: annealed polycrystal.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1; S-1,5.	F.A. Andrews, R. T. Webber, and D.A. Spohr (1951).
P.S.J.	Alcoa; > 99.99% pure.	Cold-drawn, reduced 55%.	A-1; B-1; C-1; D-1(2); E-1; F-2; G-2; L-1; M-1.	R.W. Powers, D. Schwartz, and H. L. Johnston (1951).
M.R.	Johnson, Matthey 4899; 99.994% pure.	Annealed.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1.	K. Mendelssohn and H.M. Rosenberg (1952 a).
See FIGURE 73	. . . . .	Measured the superconducting state below 1 K.	. . . . .	K. Mendelssohn and C.A. Renton (1953).
R.	Same as M.R. above; RRR(20) = 279.	Annealed in vacuum for several hours at 600°C.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1; S-1,5.	H.M. Rosenberg (1955).
H.M.Z.	99.998% pure.	Annealed in vacuum for 5 hrs. at 500°C.	A-1; B-1; C-1; D-3(2); F-4; G-3; M-1; S-3.	D.H. Howling, E. Mendoza, and J. E. Zimmerman (1955).
P.-1, 2; also see FIGURE 73	#1: 0.001% Cu, Mg, and Si. #2: 0.068% Cu; 0.004% Fe; 0.003% Si; 0.001% Mn; 6 ppm Mg (weight percent).	Cold-drawn. Also measured in the superconducting state below 1 K.	A-1; B-5; C-1; D-3(2); E-6; F-4; G-3; M-1; N-3.	L. Passell (1955).
See FIGURE 73	. . . . .	Measured both the normal and superconducting states below 1 K.	. . . . .	N.V. Zavaritskii (1958).

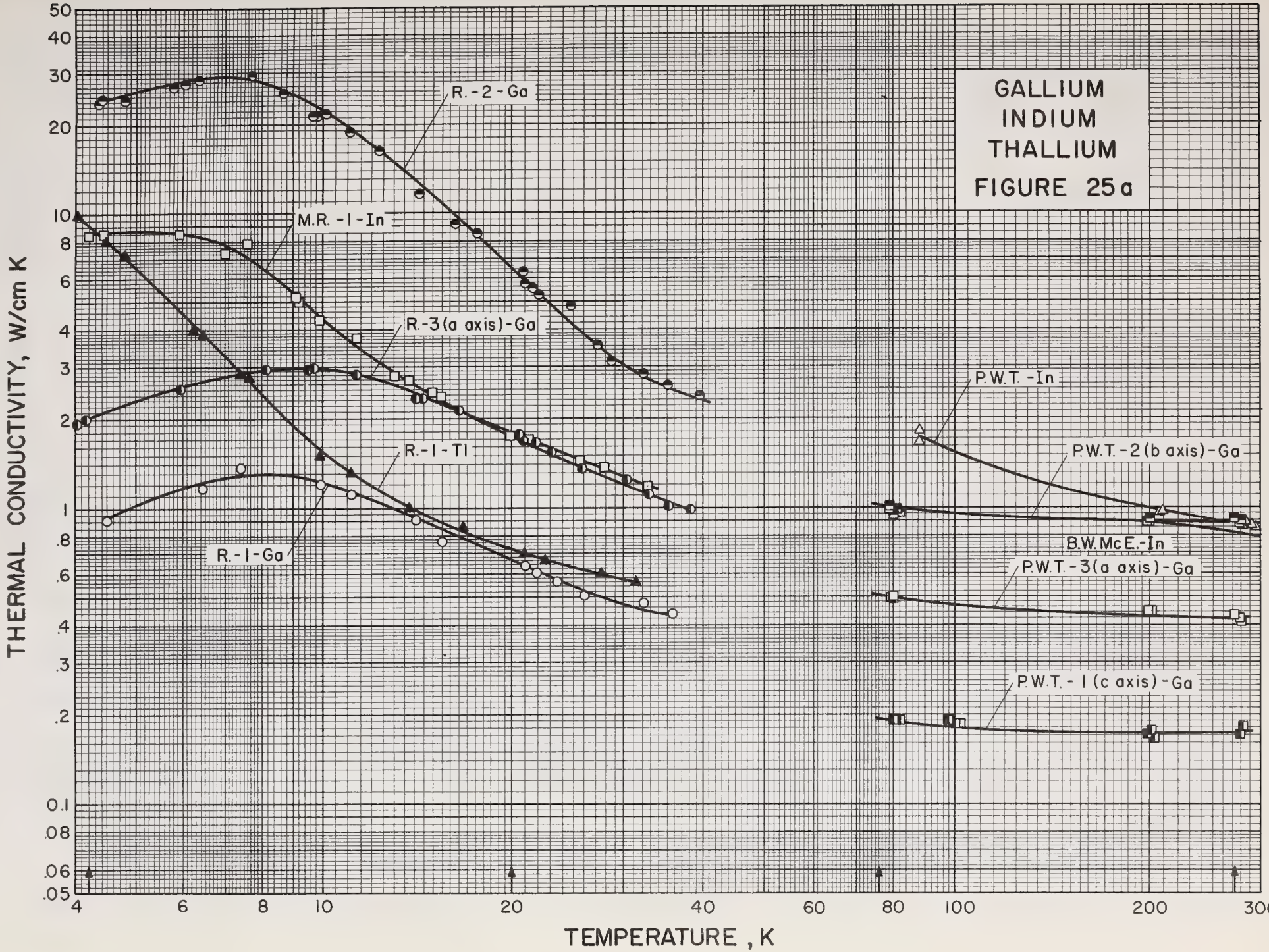
ALUMINUM (cont'd)
(See FIGURES 24a and 24b)

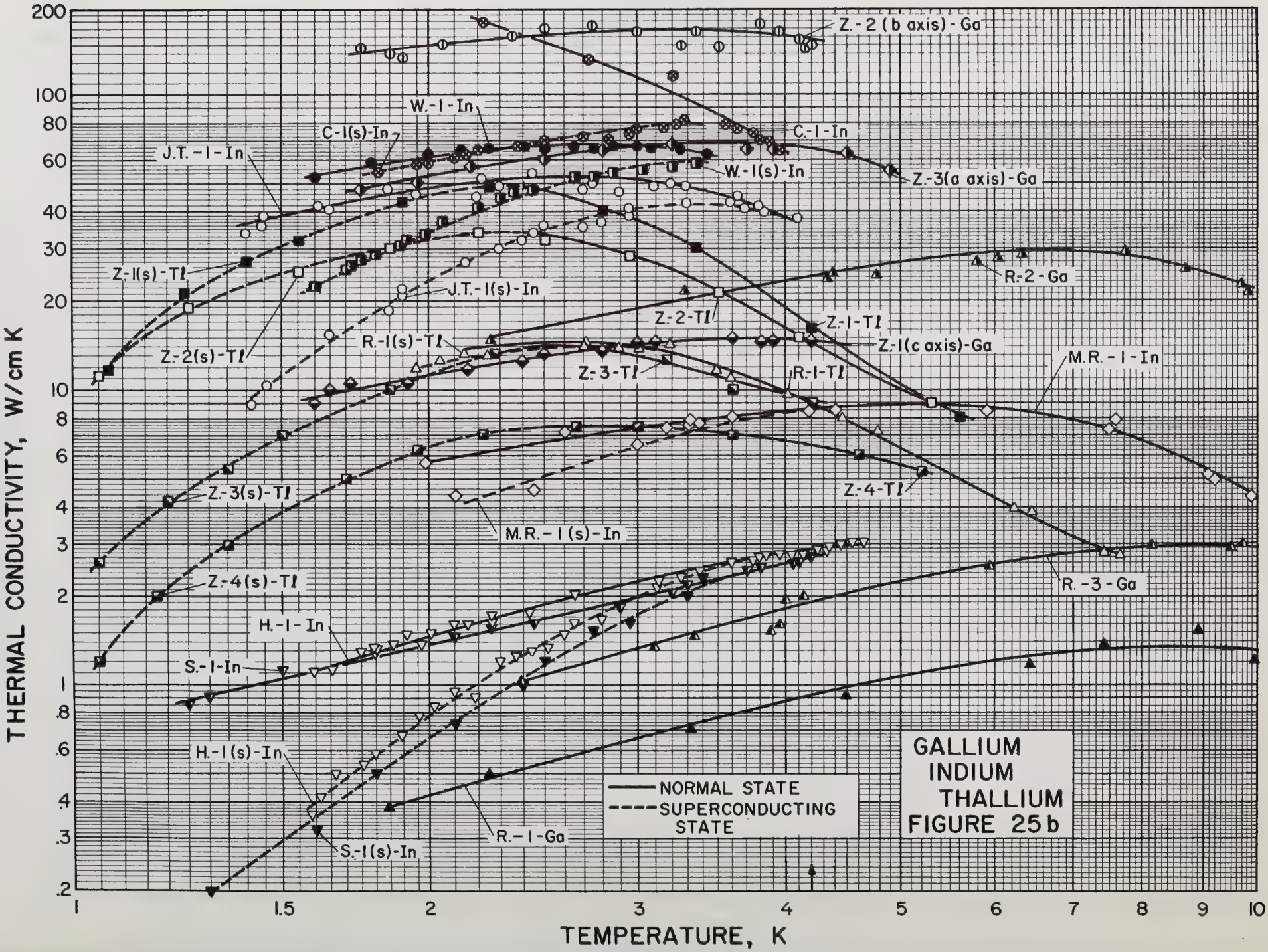
CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
P.H.R.-1,2,3	#1: Johnson, Matthey 340; 99.995% pure. #2: Alcoa; commercially-pure 1100-F; 0.13% Si, 0.1% Cu, Ga, Fe, Mg, V; 0.02% Cr; 0.01% Mn, Pb, Sn, Ti; 0.001% Ca and Zr. #3: Alcoa; commercially-pure 1100-0; 0.41% Fe; 0.22% Si; 0.1% Cu, Ga, Mg, Mn; 0.01% Cr, Pb, Ti, V, Zn; 0.001% Ca, Zr; 0.0001% Bi.	#1: single crystal; reduced, chemically etched, annealed in vacuum for 2 hrs. at about 400°C. Inclination: [001] line 6° to rod axis; [011] line 40° to rod axis; [111] line 50° to rod axis. #2: rod turned down and drawn from a flat sheet; inclusions of Si primary crystals; "as fabricated condition. Average grain size: 0.024×0.008, longitudinal; 0.012, transverse. Diamond point hardness: 24, longitudinal; 21, transverse. #3: after fabrication, annealed in vacuum for 1 hr. at 350°C; Si primary crystals; $FeAl_3$ inclusions. Average grain size: 0.040×0.032, longitudinal; 0.036, transverse. Diamond point hardness: 11, longitudinal; 13, transverse. Table of intrinsic thermal resistivity.	A-3; B-1; C-1; D-1(8); F-3; G-1; L-1,2; M-1,2; N-1; S-1,2,5.	R.L. Powell, W.J. Hall, and H. M. Roder (1960); also W.J. Hall, R.L. Powell and H.M. Roder (1960).
D.G.	99.5% pure.	Average curve of 5 curves obtained at different currents. Values were current dependent.	A-3; B-1; C-1; D-2(2); F-4; G-2; L-1; M-1.	E. Donth and C. Gladun (1962).
F.R.W.-1,2	Cominco; 99.9999% pure.	Annealed in air for 10 minutes at 550°C. Zone refined. Rolled, drawn, and etched. Graph of intrinsic thermal resistivity.	A-1; B-1; C-1; D-4(2); E-1,5; F-4; G-1; L-1,2; M-1; S-1,5.	E.W. Fenton, J.S. Rogers, and S.B. Woods (1963).
G.H.	99.99% pure.	. . . . .	A-1; B-1; C-1; D-2(2); F-4; G-3.	C. Gladun and W. Holzhäuser (1964).
P.T.W.	99.993% pure.	. . . . .	A-1; B-1; C-1; D-1(2); F-4; G-2; S-1.	R.W. Powell, R.P. Tye, and M. J. Woodman (1965).
See FIGURE 73	. . . . .	Measured both the normal and superconducting states below 1 K.	. . . . .	K. Mendelssohn, J. K.N. Sharma, and I. Yoshida (1965).
. . . . .	. . . . .	Measured effect of transverse magnetic fields on thin films of aluminum at 4.2 K.	. . . . .	T. Amundson and T. Olsen (1965).
M.McE.B.	Reynolds Aluminum; 99.999% pure; RRR ~ 520.	Machined from stock. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-1(2); E-1; F-1; G-1; L-1,2; S-1,2,5.	J.P. Moore, D.L. McElroy, and M. Barisoni (1966).

ALUMINUM (cont'd)

(See FIGURES 24a and 24b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
S.O.-1,2	Vigeland Brug; Super Purity, > 99.9996% pure. #1: RRR (20) = 24,000. #2: RRR (20) = 15,000.	Zone refined, cold-rolled, then drawn. Annealed in air for 24 hrs. at 480°C. Graph of intrinsic thermal resistivity.	A-1; B-1; C-1; D-3(2); E-3,5; G-2; L-1; M-1; N-1; S-1,5.	P. Seeberg and T. Olsen (1967).
See FIGURE 73	. . . . .	Measured both the normal and superconducting states below 1 K.	. . . . .	J.K.N. Sharma (1967a).
W.P.	Advanced Research Materials; 99.99989% pure (by difference); 0.5 ppm Cu and Si; 0.1 ppm Mg.	Specific density of 2.698 at 23°C.	A-1; B-1; C-1; D-1(3); E-2; F-4; G-2; S-1.	K.E. Wilkes and R.W. Powell (1968).


GALLIUM
INDIUM
THALLIUM
FIGURE 25a
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
R.-2-Ga
M.R.-1-In
R.-3(a axis)-Ga
R.-1-Tl
R.-1-Ga
P.W.T.-In
P.W.T.-2(b axis)-Ga
B.W.McE.-In
P.W.T.-3(a axis)-Ga
P.W.T.-1(c axis)-Ga
50
40
30
20
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
0.1
.08
.06
.05
4
6
8
10
20
40
60
80
100
200
300


THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
200
100
80
60
40
30
20
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
1
1.5
2
3
4
5
6
7
8
9
10
Z.-2 (b axis)-Ga
W.-1-In
C-1(s)-In
C.-1-In
J.T.-1-In
W.-1(s)-In
Z.-3(a axis)-Ga
Z-1(s)-Tl
R.-2-Ga
J.T.-1(s)-In
Z.-2-Tl
Z.-1-Tl
R.-1(s)-Tl
Z.-1(c axis)-Ga
Z.-2(s)-Tl
Z.-3-Tl
R.-1-Tl
M.R.-1-In
Z.-3(s)-Tl
Z.-4-Tl
M.R.-1(s)-In
Z.-4(s)-Tl
R.-3-Ga
H.-1-In
S.-1-In
H.-1(s)-In
R.-1-Ga
S.-1(s)-In
NORMAL STATE
SUPERCONDUCTING STATE
GALLIUM
INDIUM
THALLIUM
FIGURE 25b

GALLIUM
(See FIGURES 25a and 25b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	A rough comparative measurement showed a 5:1 anisotropy between ice and CO_2 temperatures.	. . . . .	R.W. Powell (1951).
. . . . .	. . . . .	Measurements made on three single crystals where the rod directions were of high, low, and intermediate electrical resistance. Measurements made in longitudinal and magnetic fields up to 0.04 T.	. . . . .	K. Mendelssohn and H.M. Rosenberg (1953).
. . . . .	. . . . .	Measured anisotropies of crystals in 3 principal directions between 4 and 20 K.	. . . . .	H.H. Plumb and J. A. Marcus (1954).
R.-1, 2, 3-Ga	National Physical Laboratory. #1: RRR(20) = 92.1. #2: RRR (20) = 111. #3: RRR(20) = 106.5.	Single crystals, all from same batch of metal. #1, #2, #3: based on quoted electrical resistivity ratios, the rod axes were probably within 10° of the c, b, and a directions, respectively.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1; N-4; S-1, 5.	H.M. Rosenberg (1955).
Z.-1(c axis), 2(b axis), 3(a axis)-Ga; also see FIGURE 73	~0.001% impurities. #1: RRR (20) = 21,000. #2: RRR (20) = 14,000. #3: RRR(20) = 23,000.	Single crystals, grown by Kapitza method. #1: grown along the c crystallographic direction. #2: grown along the b crystallographic direction #3: grown along the a crystallographic direction All directions within accuracy of 10°. Graph of reduced electronic thermal conductivity. Also measured below 1 K.	A-3; B-1; C-1; D-3(4); E-6; F-4; G-2; L-1, 2; M-1; N-3, 4; P-5.	N. V. Zavaritskii (1960a).
See FIGURE 73	. . . . .	Measured the superconducting state below 1 K.	. . . . .	N. V. Zavaritskii (1960b).
. . . . .	. . . . .	Measured the thermal conductivity of the solid and liquid near the melting point.	. . . . .	B.P. Pashaev (1961).
P.W.T-1(c axis), 2(b axis), 3(a axis)-Ga	National Chemical Laboratory.	Single crystal rods. #1: axis conformed to within 10° of the c axis. #2: axis conformed to within 10° of the b axis. #3: axis conformed to within 10° of the a axis. Tables of electronic and lattice thermal conductivity.	A-1; B-1; C-1; D-1(2); F-4; G-2; L-1, 2; N-4; S-1, 5.	R.W. Powell, M. J. Woodman, and R.P. Tye (1963).

GALLIUM (cont'd)

(See FIGURES 25a and 25b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	99.99 - 99.9999% pure.	Measured the boundary scattering and effects of size and crystal orientation on thermal conductivity between 1 and 4.2 K. The crystal with the maximum value had k = 845 at 1.77 K. Plot of WT versus T^3.	A-1; B-1; C-1; D-(2); G-2; L-1, 3; M-1; N-4, 7.	R.I. Boughton and M. Yaqub (1968).
. . . . .	. . . . .	Measured the total and lattice thermal conductivity of gallium single crystals in the normal and superconducting states in the temperature range 1-100 K.	. . . . .	F.W. Gorter and L.J. Noordermeer (1970).

INDIUM

(See FIGURES 25a and 25b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	Hilger; "pure"; RRR = 72.	Resistance measurements were made in zero field from 2.1 to 94 K and in transverse and longitudinal magnetic fields up to 0.066 T at 2.1 K. Absolute values were not determined.	. . . . .	W.J. de Haas and H. Bremmer (1932 a).
H.-1, 1(s)-In	Johnson, Matthey; "chemically pure"; 0.1% (weight) impurities.	Prepared by casting in glass tubes. Homogeneous solid solution; few large crystals. Measured in both the normal (in longitudinal magnetic fields ranging up to 0.15 T) and superconducting (s) states. T_c = 3.40 K. Graph of the ratio of superconductive to normal thermal conductivity as a function of reduced temperature.	A-1; B-1; C-1; D-4(2); E-5; F-4; G-2; L-1, 2; M-1; N-2, 3; S-1.	J.K. Hulm (1950).
. . . . .	Johnson, Matthey 3249; RRR = 5500.	Single crystal. Measured thermal conductivity in the intermediate state as a function of transverse magnetic fields. Graphs of the thermal conductivity as a function of the transverse magnetic fields up to 0.02 T.	. . . . .	D.P. Detwiler and H.A. Fairbank (1952 a, b).
M.R.-1, 1(s)-In	Johnson, Matthey 4398; 99.993% pure.	Unannealed. Measured in both the normal and superconducting (s) states.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1; N-3.	K. Mendelssohn and H. M. Rosenberg (1952 a).
. . . . .	Same as M.R. above.	Same specimen as M.R. above measured in transverse magnetic fields up to 0.04 T.	. . . . .	K. Mendelssohn and H. M. Rosenberg (1953).
See FIGURE 73	. . . . .	Measured in the superconducting state below 1K.	. . . . .	K. Mendelssohn and C.A. Renton (1953, 1955).
. . . . .	Same as M.R. above.	Review of M.R. above.	. . . . .	H.M. Rosenberg (1955).

INDIUM (cont'd)

(See FIGURES 25a and 25b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
S.-1, 1(s)-In	99.95% pure.	Single crystal; grown in pyrex tubes; etched. T_c = 3.374 K. Measured in both the normal (in longitudinal magnetic fields up to 0.1 T) and superconducting (s) states. T_c = 3.374 K. Graph of the ratio of superconductive to normal thermal conductivity as a function of reduced temperature.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-2; M-1; N-2, 3.	R. J. Sladek (1955).
See FIGURE 73	. . . . .	Measured below 1 K.	. . . . .	G. M. Graham (1958).
J. T.-1, 1(s)-In	"Spectroscopically pure".	Extruded. Grain size ~ 0.1 mm. Measured in both the normal and superconducting (s) states. T_c = 3.407 K. Graph of the change of the thermal resistance as a function of longitudinal magnetic fields.	A-1; B-1; C-1; D-3; E-5; G-3; L-1, 2; M-1, 4; N-2, 3; S-1, 5.	R. E. Jones and A. M. Toxen (1960).
. . . . .	Johnson, Matthey; commercial purity; commercial; and spectroscopic purity; RRR (20) = 900, 2300, and 8000.	Single crystals; [100] orientation. k = 19, 32, and 56 at the transition temperature; T_c = 3.388 K. Graph of the ratio of superconductive to normal thermal conductivity as a function of reduced temperature.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-2; L-1, 2; M-1; N-2, 3; S-1.	A. M. Guénault (1961).
P. W. T.-In	Johnson, Matthey; < 300 ppm impurities (probably Pb and Sn).	Density of 7.334 g/cm^3.	A-1; B-1; C-1; D-1(3); F-4; G-2; O-1; S-1, 5.	R. W. Powell, M. J. Woodman, and R. P. Tye (1962).
. . . . .	. . . . .	Graph of the ratio of reduced thermal resistivity in the intermediate and superconducting states as a function of reduced magnetic fields.	. . . . .	S. Strässler and P. Wyder (1963).
. . . . .	. . . . .	Magnetic field effects on superconducting films.	. . . . .	D. E. Morris and M. Tinkham (1964).

INDIUM (cont'd)
(See FIGURES 25a and 25b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
W.-1, 1(s)-In	"High purity".	Extruded through sapphire nozzles, self-annealed for several weeks at room temperature. 1.48 mm diameter. Measured four other thin wire specimens with diameters ranging from 0.094 to 0.485 mm, whose values ranged a maximum of 50% lower at 3.5 K and 80% lower at 1.5 K; the thinnest wire had the lowest values. Measured in both the normal (in a longitudinal field) and superconducting (s) states.	L-1; M-1; N-3, 7.	P. Wyder (1964).
See FIGURE 73	. . . . .	Measured below 1 K.	. . . . .	R. H. March and O. G. Symko (1965).
. . . . .	. . . . .	Graph of the ratio of thermal conductivity of the normal and superconducting states as a function of reduced temperature. Graph of lattice conductivity as a function of temperature.	. . . . .	P. Lindenfeld and H. Rohrer (1965).
See FIGURE 73	. . . . .	Values between 1 and 1.4 K range from 0.064 to 0.09. Also measured below 1 K.	. . . . .	P. Lindenfeld, E. A. Lynton, and R. Soulen (1965).
. . . . .	. . . . .	Thermal conductivity of thin films between 1 and 4 K. Graph of the ratio of thermal conductivity of the normal and superconducting states as a function of reduced temperature for thin and thick films.	. . . . .	T. B. Greenslade, Jr. (1965).
. . . . .	. . . . .	Size effects in the intermediate state.	. . . . .	J. L. Olsen, A. Waldvogel, and P. Wyder (1966).
C-1, 1(s)-In	Consolidated Mining and Smelting; 99.9999% pure; RRR(22) = 20,000.	Rolled between Teflon plates. Measured in both the normal (in longitudinal magnetic fields up to 1.5 T) and superconducting (s) states. Graph of the ratio of thermal resistivity of the normal and superconducting states as a function of reduced temperature.	A-1; B-4; C-1; D-3(2); E-5; F-4; G-2; L-1, 2; M-1; N-2, 3; S-1, 5.	M. E. de la Cruz, F. de la Cruz, J. M. Cotignola, O. J. Bressan, and C. A. Luengo (1968).

INDIUM (cont'd)

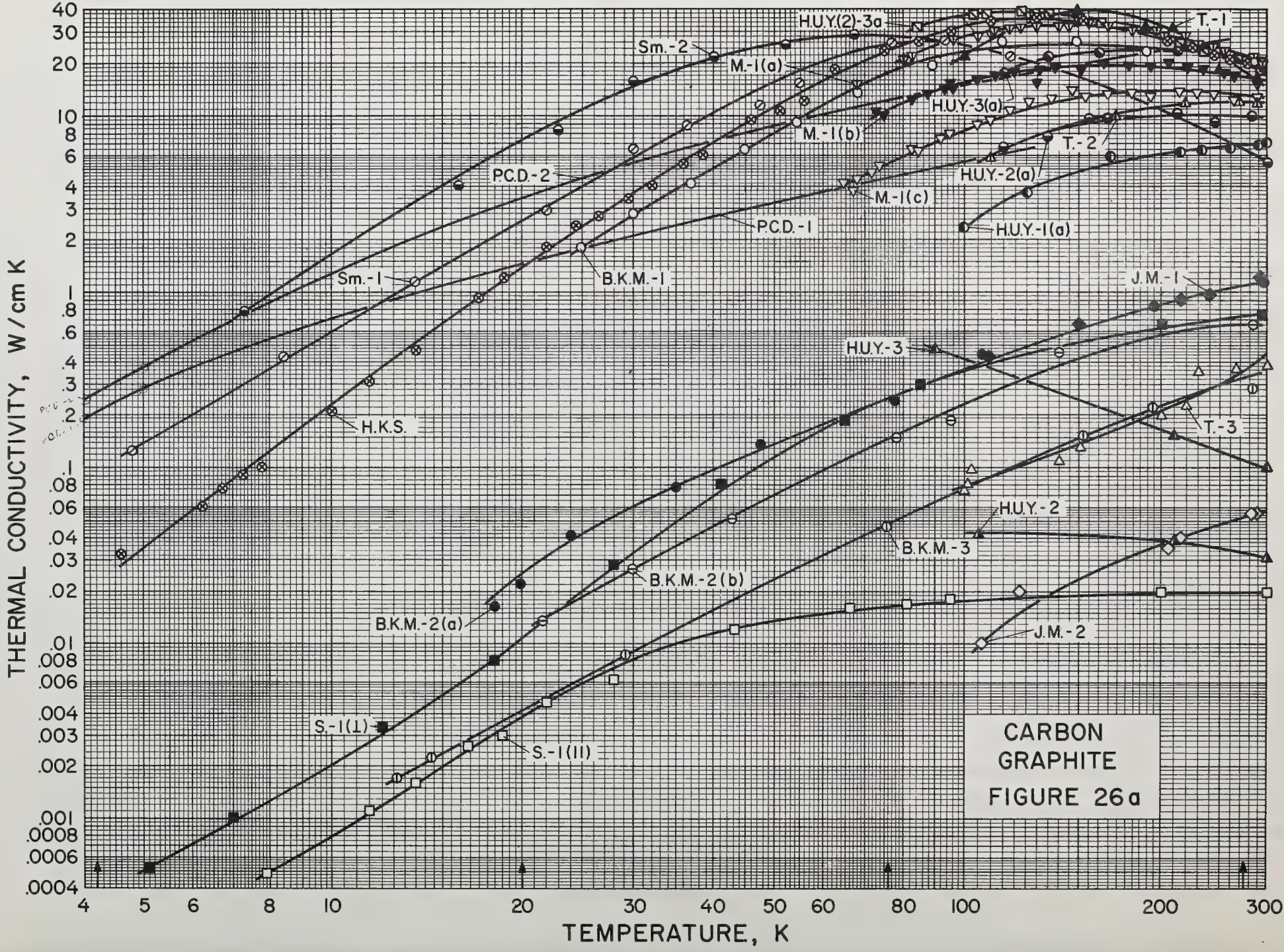
(See FIGURES 25a and 25b)

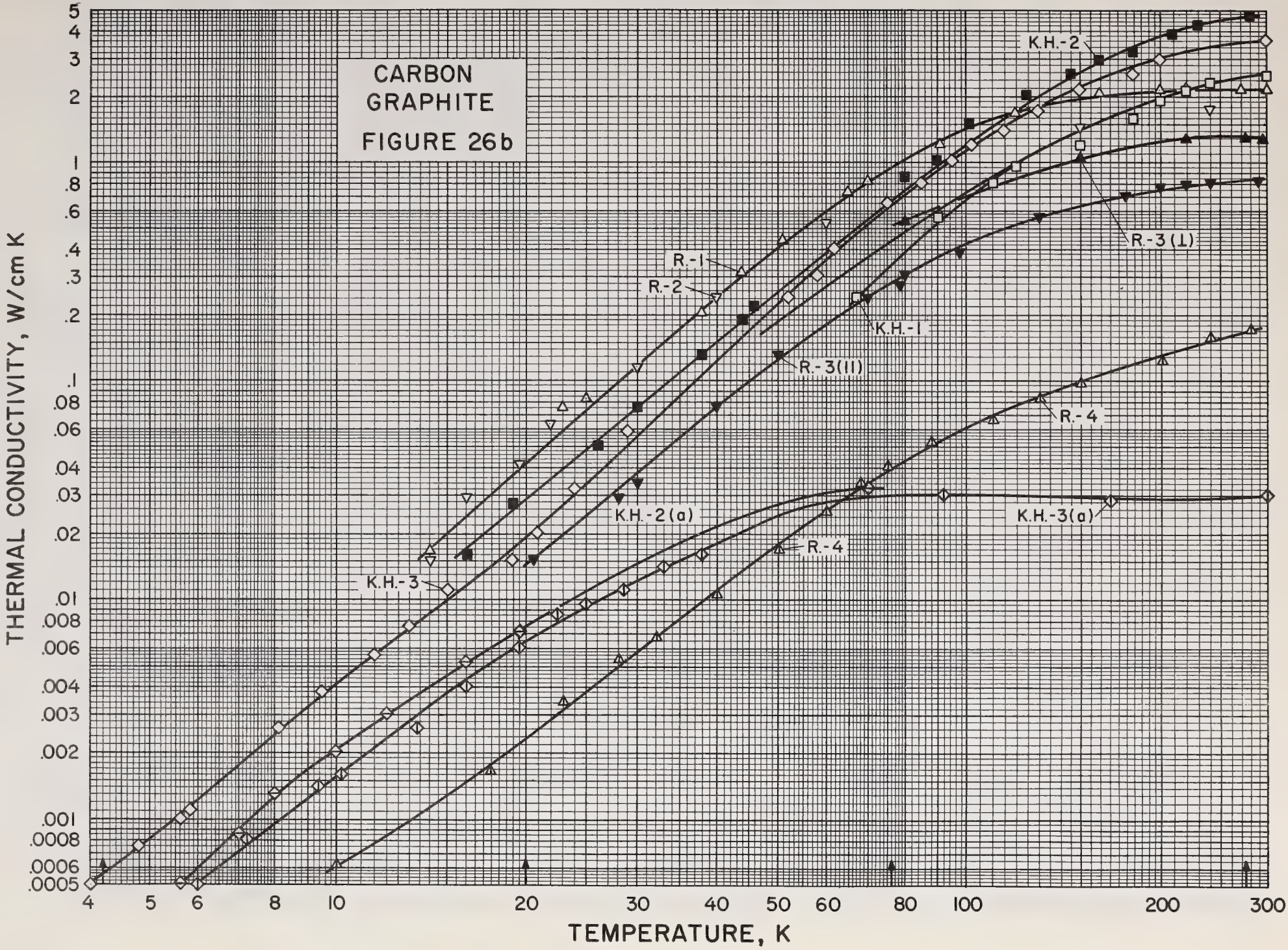
CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
B.W.McE-In	Semi Elements; total metallic impurities < 100 ppm. #1: 20 ppm Ag; 15 ppm Si; 4 ppm Ca, Cd, and K; 2 ppm Bi, Cu, Ti, Tℓ, and S; 1.5 ppm Fe; 1 ppm Pb and Zn; < 1 ppm Aℓ, B, Co, Cr, Mg, Mn, Na, Sc, and Th; RRR = 10,900. #2: 30 ppm Ag and Zn; 10 ppm Cd; 7 ppm Tℓ and S; 5 ppm Fe; 4 ppm Pb; 1.5 ppm Cr and Si; 1 ppm Ca, K, and Sc; < 1 ppm Aℓ, B, Bi, Co, Mg, Mn, Ni, and Ti; RRR = 10,700.	All specimens produced from one lot. #1: single crystal; density of 7.285 g/cm^3. Rod axis 81.5° to [001] direction, within 2°. Another similar single crystal specimen had identical density and chemical analysis; RRR = 7600; rod axis 41.5 ° to [001] direction, within 2°. #2: fairly coarse-grained polycrystal; density of 7.281 g/cm^3. Diamond pyramid hardness: 0.7 kg/mm^2, and 1.0 kg/mm^2 (at 50°, 62°, and 75° between the rod axis and the [001] direction). The two single crystal curves coincide at 90 K; the single crystal of 41.5° orientation is 3% higher than the curve at 300K. Specimen #2 is approximately the same as the curve at 300 K and 2% higher at 90 K.	A-1; B-1; C-1; D-1(2); E-1; F-1; G-1; L-1,2; N-4; O-1; S-1,2,5.	M. Barisoni, R.K. Williams, and D. L. McElroy (1968).

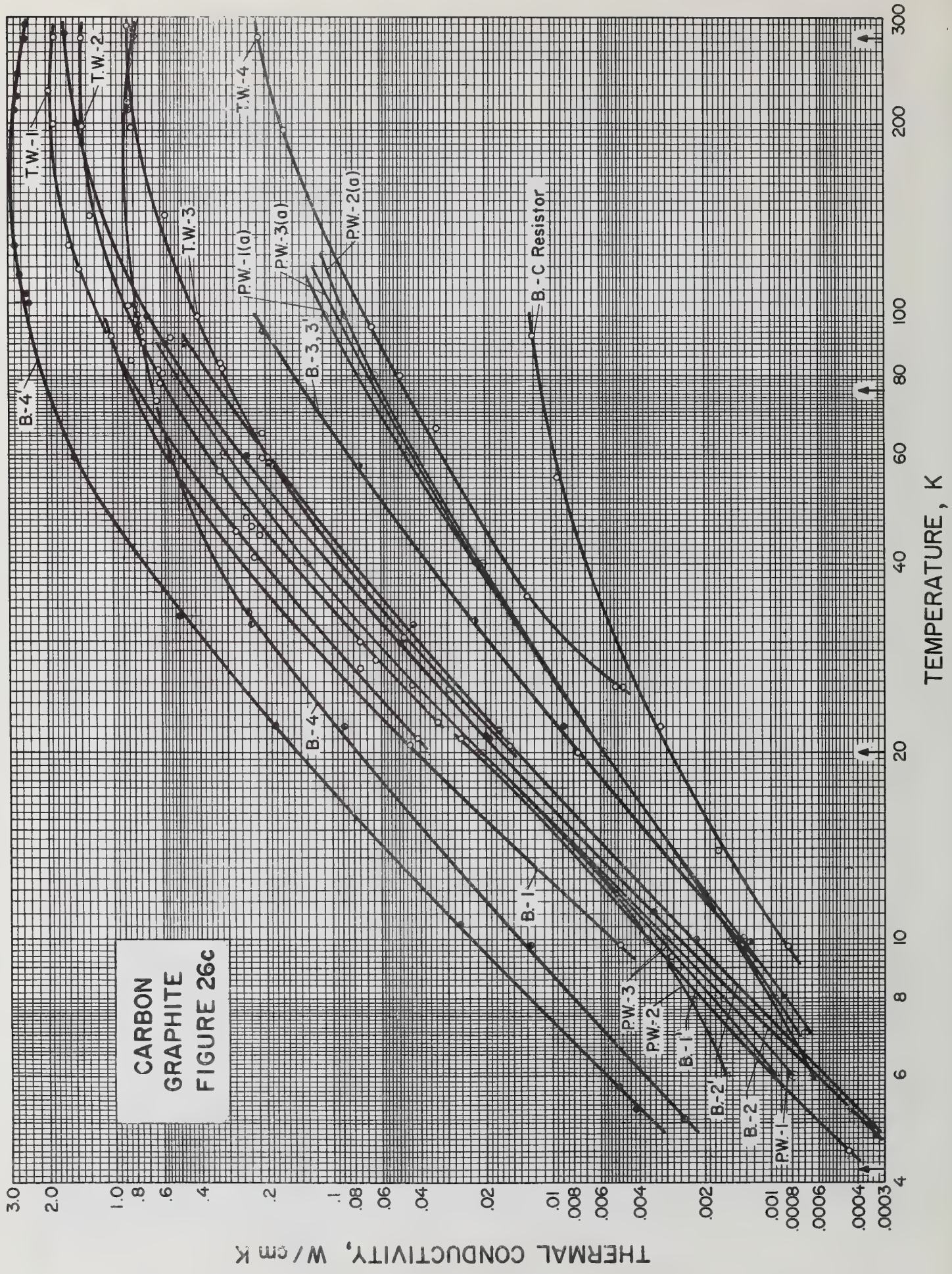
THALLIUM

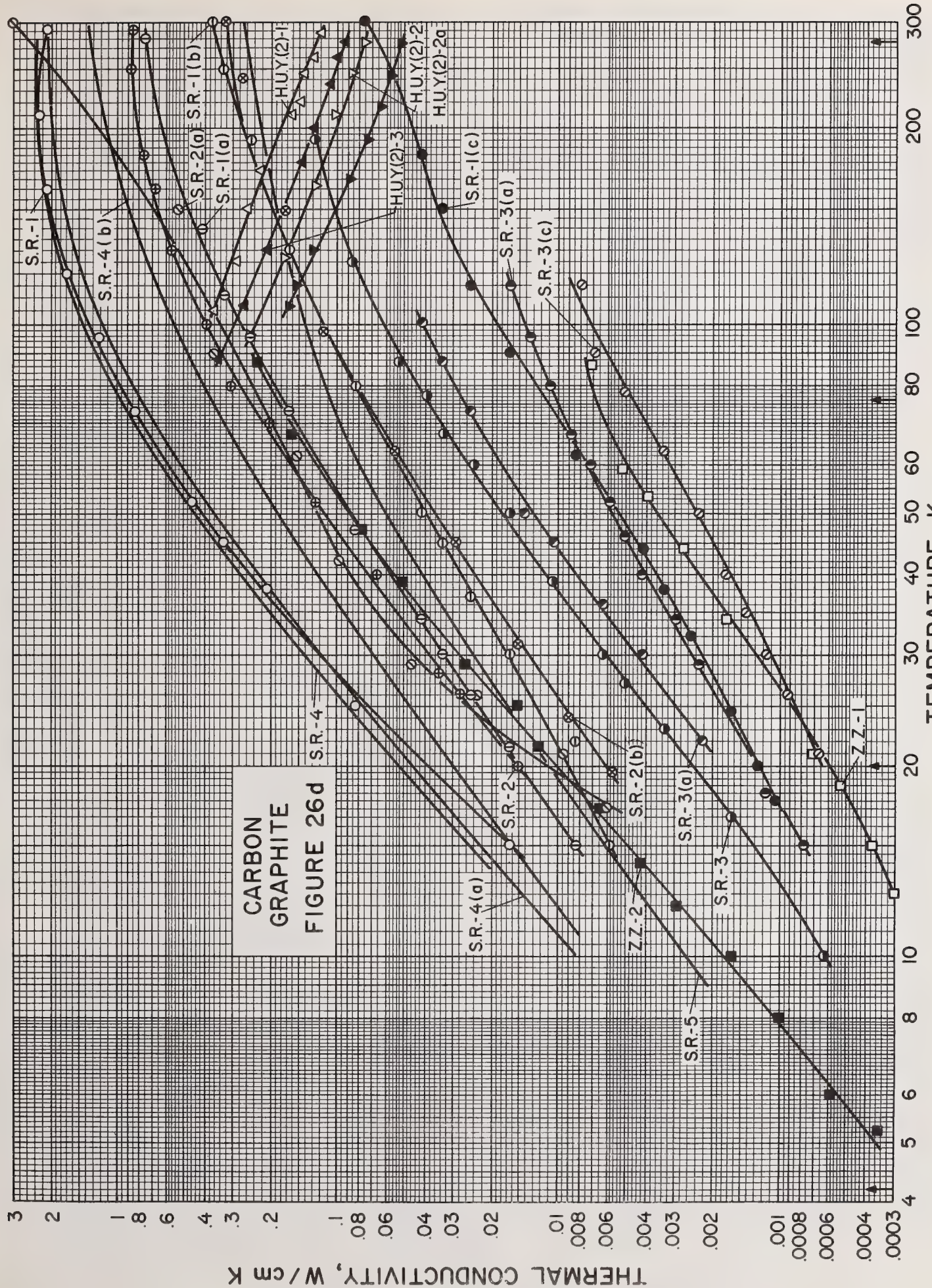
(See FIGURES 25a and 25b)

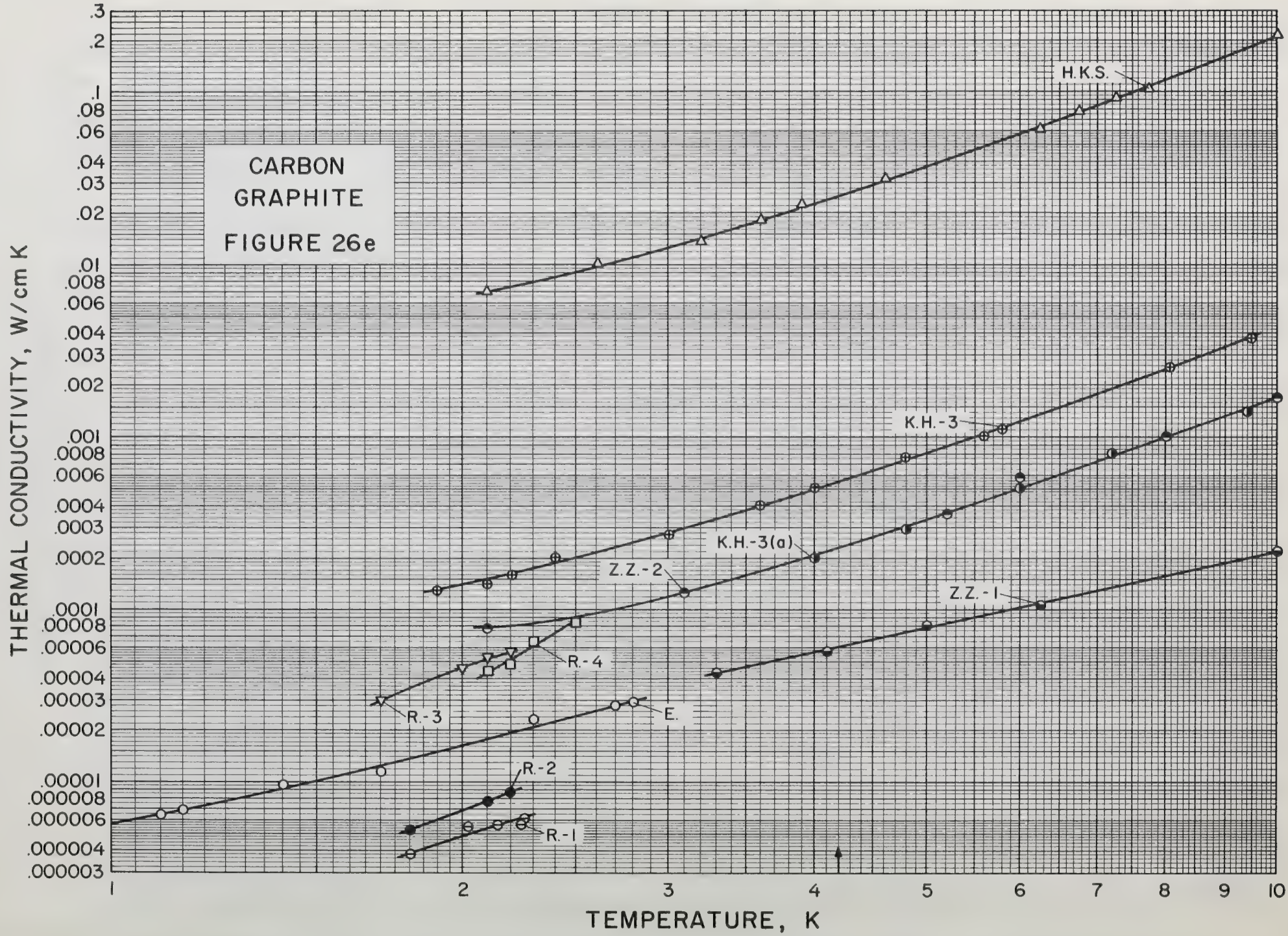
CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	Kahlbaum.	Drawn. k = 0.51 at 0°C; k = 0.64 at 80K.	A-1; B-1; C-1; D-1(2); F-4; G-3; P-1; S-1,5.	A. Eucken and K. Dittrich (1927).
. . . . .	. . . . .	Measured in transverse and longitudinal magnetic fields up to 0.4 T from 2.8 to 4.4K.	. . . . .	K. Mendelssohn and H.M. Rosenberg (1953).
See FIGURE 73	. . . . .	Measured superconducting state below 1K.	. . . . .	K. Mendelssohn and C.A. Renton (1953, 1955).
R.-1, 1(s)-Tℓ	Johnson, Matthey 2544; 99.99% pure.	Annealed in vacuum for several hours. Coated with varnish. Measured in both the normal and superconducting (s) states. T_c = 2.38K.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1,2; M-1; N-3; S-1,5.	H.M. Rosenberg (1955).
Z.-1, 1(s), 2, 2(s), 3, 3(s), 4, 4(s)-Tℓ; also see FIGURE 73	. . . . .	#1 and #2: rod axis 30° with the hexagonal axis; #2 made by etching #1. #3: rod axis 20° with the hexagonal axis. #4: rod axis 80° with the hexagonal axis. Measured in both the normal and the superconducting (s) states. Also measured the superconducting state below 1K. Graph of the ratio of the thermal conductivity of the normal and superconducting states as a function of the reduced temperature.	A-1; B-1; C-1; D-3(4); E-6; F-4; G-2; M-5; N-1,3,4; P-1; S-1,5.	N.V. Zavaritskii (1961).


THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
40
30
20
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
.01
.008
.006
.004
.003
.002
.001
.0008
.0006
.0004
4
5
6
8
10
20
30
40
50
60
80
100
200
300
H.U.Y.(2)-3a
T.-1
Sm.-2
M.-1(a)
H.U.Y.-3(a)
M.-1(b)
T.-2
P.C.D.-2
H.U.Y.-2(a)
M.-1(c)
P.C.D.-1
H.U.Y.-1(a)
B.K.M.-1
Sm.-1
J.M.-1
H.U.Y.-3
H.K.S.
T.-3
H.U.Y.-2
B.K.M.-3
B.K.M.-2(b)
B.K.M.-2(a)
J.M.-2
S.-1(⊥)
S.-1(II)
CARBON
GRAPHITE
FIGURE 26a


CARBON
GRAPHITE
FIGURE 26b
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
5
4
3
2
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
.01
.008
.006
.004
.003
.002
.001
.0008
.0006
.0005
4
5
6
8
10
20
30
40
50
60
80
100
200
300
K.H.-2
R.-3 (⊥)
R.-1
R.-2
K.H.-1
R.-3(II)
R.-4
K.H.-2(a)
K.H.-3(a)
R.-4
K.H.-3


CARBON
GRAPHITE
FIGURE 26c
T.W-1
T.W-2
T.W-3
T.W-4
B-4''
B-4
B-3, 3'
B-1
B-1'
B-2
B-2'
PW-1
PW-2
PW-3
PW-1(a)
PW-2(a)
PW-3(a)
B.-C Resistor
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
3.0
2.0
1.0
.8
.6
.4
.2
.1
.08
.06
.04
.02
.01
.008
.006
.004
.002
.001
.0008
.0006
.0004
.0003
4
6
8
10
20
40
60
80
100
200
300


CARBON
GRAPHITE
FIGURE 26d
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
S.R.-1
S.R.-4(b)
S.R.-2(a)
S.R.-1(b)
S.R.-1(a)
H.U.Y.(2)-1
H.U.Y.(2)-3
H.U.Y.(2)-2
H.U.Y.(2)-2a
S.R.-1(c)
S.R.-3(a)
S.R.-3(c)
S.R.-4
S.R.-2
S.R.-2(b)
S.R.-4(a)
Z.Z.-2
S.R.-3(a)
S.R.-3
S.R.-5
Z.Z.-1


CARBON
GRAPHITE
FIGURE 26e
H.K.S.
K.H.-3
K.H.-3(a)
Z.Z.-2
Z.Z.-1
R.-4
R.-3
E.
R.-2
R.-1
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
.3
.2
.1
.08
.06
.04
.03
.02
.01
.008
.006
.004
.003
.002
.001
.0008
.0006
.0004
.0003
.0002
.0001
.00008
.00006
.00004
.00003
.00002
.00001
.000008
.000006
.000004
.000003
1
2
3
4
5
6
7
8
9
10

CARBON (GRAPHITE)

(See FIGURES 26a - 26e)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	From a 6H pencil.	Density of 2.11 g/cm^3; k = 0.15 at 18°C.	A-5; B-5; C-1; D-2(2); E-2; F-5; G-3.	T. Barrett and R.M. Winter (1925).
. . . . .	Acheson graphite.	k = 1.78 at 122 K; k = 1.72 at 300 K.	A-1; B-2; C-1; D-1(6); F-5; G-3; L-1; P-1.	A.P. Crary (1933).
. . . . .	National Carbon. #1 and #2: Acheson graphite. #3: carbon electrode.	#1: rod axis parallel to extrusion direction. k = 1.76 at 0°C; k = 2.5 at 82 K. #2: rod axis perpendicular to extrusion. k = 1.13 at 0°C; k = 1.76 at 82 K. #3: k = 0.060 at 0°C; k = 0.015 at at 82 K. Negative temperature coefficient for electrical resistivity.	A-5; B-1; C-1; D-1(1); F-3; G-3; N-4; S-1.	R.A. Bauerschaper (1944).
B-1, 1′, 2, 2′, 3, 3′, 4, 4′, 5	#1, 1′-3, 3′: artificial graphite. #4, 4′: National Physical Laboratory; natural graphite. #5: carbon resistor.	#1, 1′-3, 3′: made by extrusion process; very anisotropic. Unprimed numbers refer to rods with axes parallel to direction of extrusion; primed numbers refer to rods with axes perpendicular to the direction of extrusion. Densities were 1.79, 1.60, and 1.77 g/cm^3, respectively. Crystal sizes were 2000, 1000, and 300Å, respectively. #4, 4′: single crystal unprimed refers to rod axis parallel to preferred c-axis; primed refers to perpendicular. Density of 2.25 g/cm^3; crystal size of 2000Å. #5: carbon resistor; 33Ω, $\frac{1}{2}$W. Negative temperature coefficient for electrical resistivity.	A-1; B-1; C-1; D-3, 4(2); E-4; F-4; G-2; L-1; N-4; P-1, 4; S-1.	R. Berman (1952a, b).
T.W.-1, 2, 3, 4	#1: National Carbon; CS graphite. #2: National Carbon; AGOT graphite. #3: natural graphite. #4: lampblack.	#1 and #2: coke base, pitch bonded, extruded. Bulk density of 1.70 g/cm^3. Rod axes were perpendicular and parallel to the preferred c-axis, respectively. #3: pitch bonded, molded. Bulk density of 1.80 g/cm^3. Rod axis perpendicular to preferred c-axis. #4: pitch bonded, molded. Bulk density of 1.65 g/cm^3. Rod axis parallel to preferred c-axis. Negative temperature coefficient for electrical resistivity.	A-1; B-1; C-1; D-1(2); E-1; F-2; G-2; N-4; O-1; P-1; S-1, 2, 5.	W.W. Tyler and A. C. Wilson (1953).

CARBON (GRAPHITE) (cont'd)

(See FIGURES 26a–26e)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
Sm.-1, 2	National Carbon; Canadian natural graphite.	Small flakes; deformation lines on surface indicated crystallites on order of 10^{-2}cm. Positive temperature coefficient for electrical resistivity.	A-6; B-4; C-1; D-1(2); F-4; G-3; L-1; N-7;)-1, 5.	A. W. Smith (1954).
J. M.-1, 2	100 parts Kendall coke; 42 parts coal tar pitch; 2 parts vacuum wax.	Coke was calcined to 1100°C, crushed into powder, passed through a #50-Tyler sieve, extruded, and baked five days at 1100°C. Subsequently rods were heat treated, to various temperatures, in a nitrogen atmosphere, for 5 minutes. #1: rod heated to 2430°C. #2: rod heated to 1200°C. Other rods heated to 5 intermediate temperatures had intermediate values of thermal conductivity. Density of 1.49 g/cm^3. Crystallite diameters are 1050 and 37Å, respectively.	A-1; B-1; C-1; D-1(6); E-1; F-2; G-2; L-1; O-5; P-1, 5.	C. P. Jamieson and S. Mrozowski (1955).
R.-1, 2, 3(⊥), 3(∥), 4	#1: petroleum coke. #2: natural Ceylon block. #3: petroleum coke. #4: lamp black.	#1: extruded; large flour size; specimen was parallel to axis of extrusion during measurements. Density of 1.65 g/cm^3. #2: very large flake. #3: molded; medium large flour. Specimen was either perpendicular (⊥) or parallel (∥) to axis of molding pressure during measurement. Density of 1.75 g/cm^3. #4: molded; small flour size. Axis parallel to direction of molding pressure. Density of 1.55 g/cm^3. All specimens had negative temperature coefficient for electrical resistivity.	A-4; B-4; C-3; D-1(2); E-2; F-4; G-3; L-1; O-1, 5; P-1; S-1, 2, 4.	N. S. Rasor (1955).
Z. Z.-1, 2	Resin bonded graphite.	Annealed to 1500 and 2000°C respectively. Graph of lattice conductivity below 20 K.	A-1; B-1; C-1; D-3(2); E-3, 5; G-3; O-5.	N. V. Zavaritskii and A. C. Zeldovich (1956).

CARBON (GRAPHITE) (cont'd)

(See FIGURES 26a–26e)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
S.R.-1, 1(a), 1(b), 1(c), 2, 2(a), 2(b), 3, 3(a), 3(b), 3(c), 4, 4(a), 4(b), 5	#1: AGOT-KC pitch bonded coke graphite. #2: AWG graphite. #3: pitch-bonded graphitized lamp black. #4: untreated AGOT-KC graphite; treated with: (a), 0.02%(atomic)Br; (b), 1.16%(atomic)Br. #5: National Carbon; pyrolytic.	#1: extruded; estimated size of 50μ; crystallite size of 0.3μ. Density of 1.65 g/cm^3. Specimen was unirradiated, then irradiated with various neutron irradiations at about 30°C: 12.5(a); 48(b); 1927(c) mwd (mwd is megawatt-day, representing about 10^{17} nvt of neutrons with energy greater than 0.5 Mev). Also irradiated at 460 mwd. #2: molded coke. Density of 1.75 g/cm^3; particle size of 25μ; crystallite size of 0.2μ or larger. Specimen was unirradiated, then irradiated at 30°C with neutron irradiations: 6(a); 22.7(b) mwd. #3: molded. Density of 1.55 g/cm^3; particle size of 0.3μ; crystallite size of 0.05μ. Specimen was unirradiated; then irradiated at 30°C with neutron irradiations: 12.5(a); 146(b); 460(c) mwd. Also irradiated at 22.7 mwd. #4: treated. Also treated with 0.31 and 0.88% Br. #5: pyrolytic decomposition of a hydrocarbon; well graphitized; small crystallites; no pitch bonding.	A-4; B-1; C-3; D-1; G-3; M-1; O-3; P-4, 5; Q-1; S-1.	A.W. Smith and N. S. Rasor (1956).
B.K.M.-1, 2(a), 2(b), 3	#1: graphite filament. #2: petroleum coke base; equivalent bromine residue: (a), 0.25%; (b), 0.75% (weight percent). #3: lampblack base.	#1: fiber structure prepared by pyrolysis of methane on a hot carbon wire. Characterized by a high density and high preferred crystallite size of 7μ. Baked at over 3200°C. #2: moulded with coal-tar pitch. Crystallite size of a few tenths μ. Baked at 2800°C (a) and 2400°C (b). Also a specimen baked at 2600°C. #3: moulded with coal-tar pitch. Baked at over 2000°C.	A-1; B-1; C-1; D-1(2); F-2; G-3; M-1; O-5, 6; P-1, 2, 4; S-1, 5.	J.C. Bowman, J.A. Krumhansl, and J. T. Meers (1958).

CARBON (GRAPHITE) (cont'd)
(See FIGURES 26a–26e)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
S.-1(∥), 1(⊥)	General Electric Co.; pyrolytic graphite.	Deposited on a substrate of commercial graphite at 2250°C from a methane atmosphere at a total pressure of 20 mm Hg. Density of 2.194 g/cm^3. Crystallites thought to be shaped like oblate ellipsoids with rotational symmetry about the c-axis. Minor diameter of 140Å, parallel to c-axis; major diameter of 280Å. Composed of columnar bundles of diameter 0.1 cm. Measurements were parallel (∥) and perpendicular (⊥) to the c-axis.	A-1; B-1, 2; C-1; D-1(2); E-4; F-2; G-2; O-2, 5, 6; P-4; S-1.	G.A. Slack (1962).
P.C.D.-1, 2	#1: Allen-Bradley. #2: Ohmite.	#1: 10Ω, $\frac{1}{2}$W radio resistor. #2: 100Ω, 2W radio resistor.	A-1; B-2; C-1; D-1, 3(2); G-3.	R.C. Pandorf, C.Y. Chen, and J.G. Daunt (1962).
H.U.Y.-1(a), 2, 2(a), 3, 3(a)	Pyrolytic graphite.	Deposited from CH_4 at 10 cm Hg at the respective temperatures: #1, 2000°C; #2, 2180°C; and #3, 2150°C (and annealed for 30 min at 3000°C). #1 and #2: crystallites with c-axis predominately oriented perpendicular to plane of deposition; little correlation between a-axes. #3: fewer structural and crystallite defects. Specimens were cut with abrasive powder and ground with abrasive paper. Measurements taken along the c-axis; measurements also taken along the a-axis (a). Thermal conductivity measurements also taken on three other specimens and irradiated specimens.	A-1; B-4; C-1; D-1(8, 2); E-1, 5; F-4; G-3; O-2, 3, 5-7; P-2, 4, 6.	C.N. Hooker, A.R. Ubbelohde, and D.A. Young (1963).
R.-1, 2, 3, 4	#1 and #2: Allen-Bradley carbon resistors. #3: Speer carbon resistor. #4: ground-down resistor.	. . . . .	A-4; B-1; C-3; D-3(1); F-5; G-3.	J. Rafalowicz (1964).

CARBON (GRAPHITE) (cont'd)
(See FIGURES 26a–26e)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
K.H.-1, 2, 2(a), 3, 3(a)	#1 and #2: Raytheon; pyrolytic graphite. #3: High Temperature Materials; pyrolytic graphite.	All were deposited from methane onto flat plates of commercial graphite. Pyrolytic turbostratic (adjacent basel planes randomly rotated, no long-range 3-dimensional order). #1: deposition temperature, 1700°C. Density of 2.13 g/cm^3; preferred orientation of 28° (direction of crystallite c-axis relative to specimen normal); crystallite size of 180Å. #2: deposition temperature of 2300°C. Density of 2.22 g/cm^3; preferred orientation of 21°; crystallite size of 285Å. #3: deposition temperature of 2100°C. Density of 2.19 g/cm^3; preferred orientation of 22°. All specimens with a layer spacing of 3.42Å. Measurements taken along the layer planes; other measurements across the layer planes (a). Two other specimens measured.	A-1; B-1; C-1; D-1(2); E-2,3; F-4; G-2; L-1, 2; M-1; O-2, 5, 7; P-4; S-1, 5.	C.A. Klein and M. G. Holland (1964).
H.U.Y.(2)-1, 2, 2(a), 3, 3(a)	"High quality" pyrolytic graphite.	#1: deposited at 2150°C; annealed at 3250°C in induction furnace. Orientation within 3° of the c-direction. #2: hot pressed at 2850°C under 400 kg/cm^2; #2(a): then exposed at 30°C to 2 × 10^{18} fast neutrons/cm^2. #3: hot pressed at 2850°C; annealed for ½ hr under 10 kg/cm^2 at 3500°C. Specimens measured in the c-direction, except #3(a) in the basel plane. Four other specimens were also measured.	A-1; B-4; C-1; D-1(2); E-1, 5; F-2; G-2; O-2, 3, 5, 6; P-3, 4.	C.N. Hooker, A.R. Ubbelohde, and D. A. Young (1965).
. . . . .	Pyrolytic graphite.	Measured a sample of unirradiated pyrolytic graphite between 6 and 300 K. The maximum was 50 W/cm-K at 110 K; the lower portion was 33% greater than Sm.-1 at 10 K. The specimen was then irradiated by 4.7 x 10^{16} neutron/cm^2 at 77 K and measured. Then it was measured after each of five successive anneals between 170 and 450 K.	. . . . .	A. de Combarieu (1965).

CARBON (GRAPHITE) (cont'd)

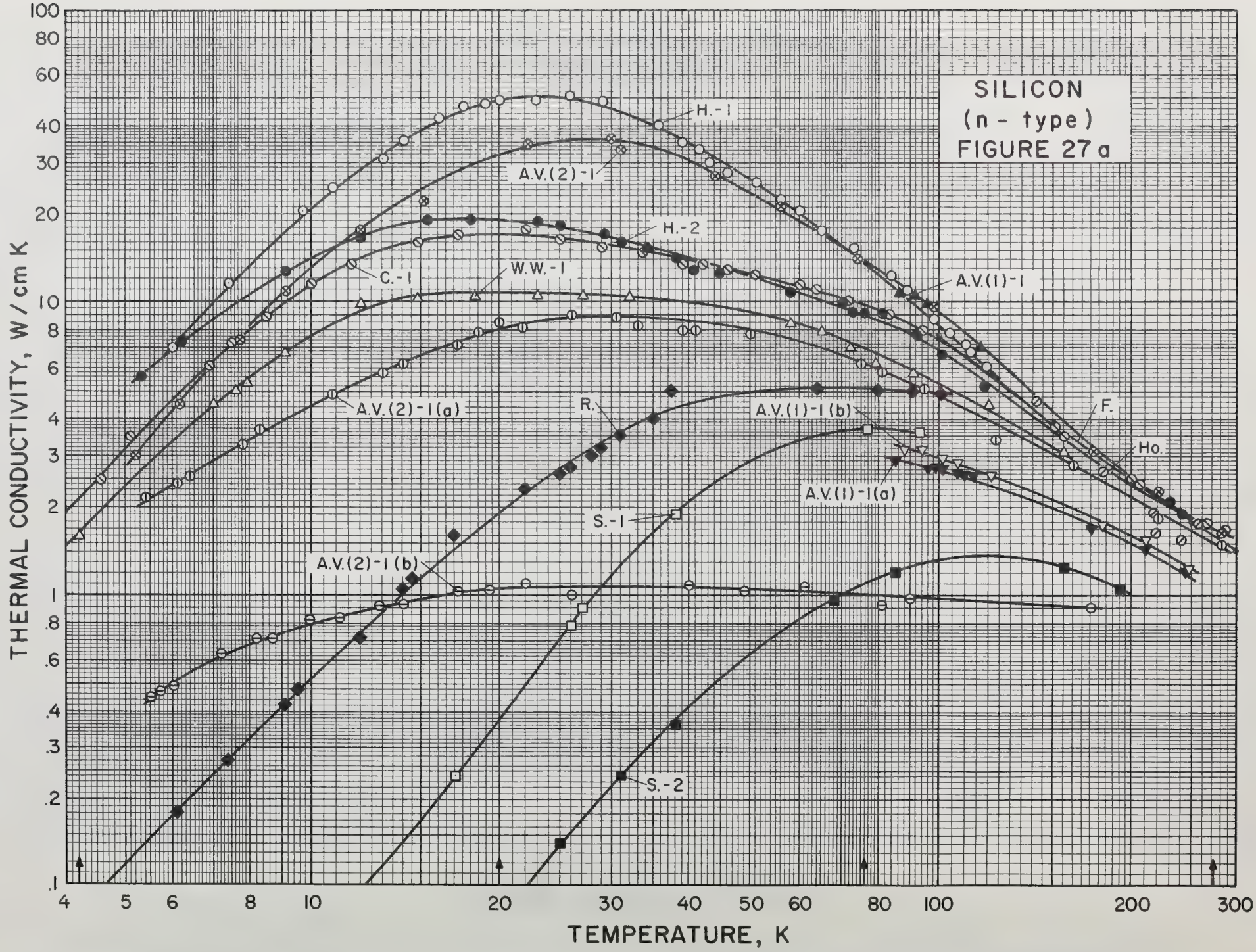
(See FIGURES 26a–26e)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
H.K.S.	"Well graphitized" pyrolytic graphite.	Highly heat-treated. Measured in the layer-plane direction. Also measured with magnetic fields up to 1.26 T in the c-direction.	A-1; B-1; C-1; D-1(2); E-2, 3; F-4; G-2; M-1; N-2, 7; P-4; R-1; S-1, 5.	M.G. Holland, C.A. Klein, and W.D. Straub (1966).
M.-1(a), 1(b), 1(c)	Pyrolytic graphite. Mobility at 300K: #1, 10.3; #2, 9.3; #3, $5.6 \times 10^3 cm^2/V$ sec. Resistivity at 300K: #1, 4.5; #2, 5.3; #3, $9.6 \times 10^{-6} \Omega cm$.	Grown on a substrate at a surface temperature of 2200°C and a propane pressure of 50 torr. Growth rate of 1.3×10^{-5} cm/sec for 1 mm thickness, then 2.6×10^{-5} cm/sec for 1.4 mm. Specimen cleaved into thin sections and measurements made as a function of the distance through the deposit. Estimated formation temperatures: 2980, 2910, 2700°C for (a), (b), and (c) respectively. Measurements were along the a-direction. Crystallite orientation half-width: 2.2, 2.4, and 25.3°, respectively. Crystallite size of 2.9, 2.1, and 1.3μ, respectively.	A-1; B-1; C-1; D-1(2); F-4; G-2; S-1, 2.	R.A. Morant (1966).
. . . . .	. . . . .	Thermal conductivity of three specimens of well-oriented annealed pyrolytic graphite calculated from thermal diffusivities determined by the heat-pulse method.	. . . . .	R. Taylor (1966).
E.; also see FIGURE 76	Union Carbide; AGOT nuclear grade.	Extruded; measurements were parallel to the extrusion direction. Also measured below 1K.	A-1; B-1; C-1; D-3(2); G-3.	D.O. Edwards, R. E. Sarwinski, P. Seligmann, and J.T. Tough (1968).
. . . . .	. . . . .	Thermal conductivities of two anisotropic graphites, both parallel and perpendicular to the direction of extrusion, and two isotropic graphites of different densities, calculated from thermal diffusivities determined by the heat-pulse method.	. . . . .	R. Taylor, K.E. Gilchrist, and L. J. Poston (1968).
. . . . .	. . . . .	Thermal conductivities of highly oriented pyrolytic graphite irradiated to selected doses and during post-irradiation annealing, calculated from thermal diffusivities determined by the heat-pulse method.	. . . . .	R. Taylor, B.T. Kelly, and K.E. Gilchrist (1969).

CARBON (GRAPHITE) (cont'd)

(See FIGURES 26a–26e)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
P.W.-1, 1(a), 2, 2(a), 3, 3(a)	#1: Graphite Specialties; Graph-i-tite G grade. #2 and #3: Great Lakes Carbon; H4LM grade.	#1: rod axis parallel to grain direction. #2: rod axis parallel to grain direction. #3: rod axis perpendicular to grain direction. Specimens (a) were irradiated at 5 MW level, integrated neutron dose of 1.73×10^{18} nvt, total gamma 3×10^{9} rads, at a temperature less than 50°C; stored at 0°C until measurement.	A-1; B-1; C-1; D-1(8); E-2, 5; F-2; G-2; M-1; P-1; S-1, 5.	R. L. Powell and P. Wagner (1970).


SILICON
(n - type)
FIGURE 27a
THERMAL CONDUCTIVITY, W / cm K
TEMPERATURE, K
H.-1
A.V.(2)-1
H.-2
C.-1
W.W.-1
A.V.(1)-1
A.V.(2)-1(a)
R.
A.V.(1)-1(b)
F.
Ho.
A.V.(1)-1(a)
S.-1
A.V.(2)-1(b)
S.-2
100
80
60
40
30
20
10
8
6
4
3
2
1
.8
.6
.4
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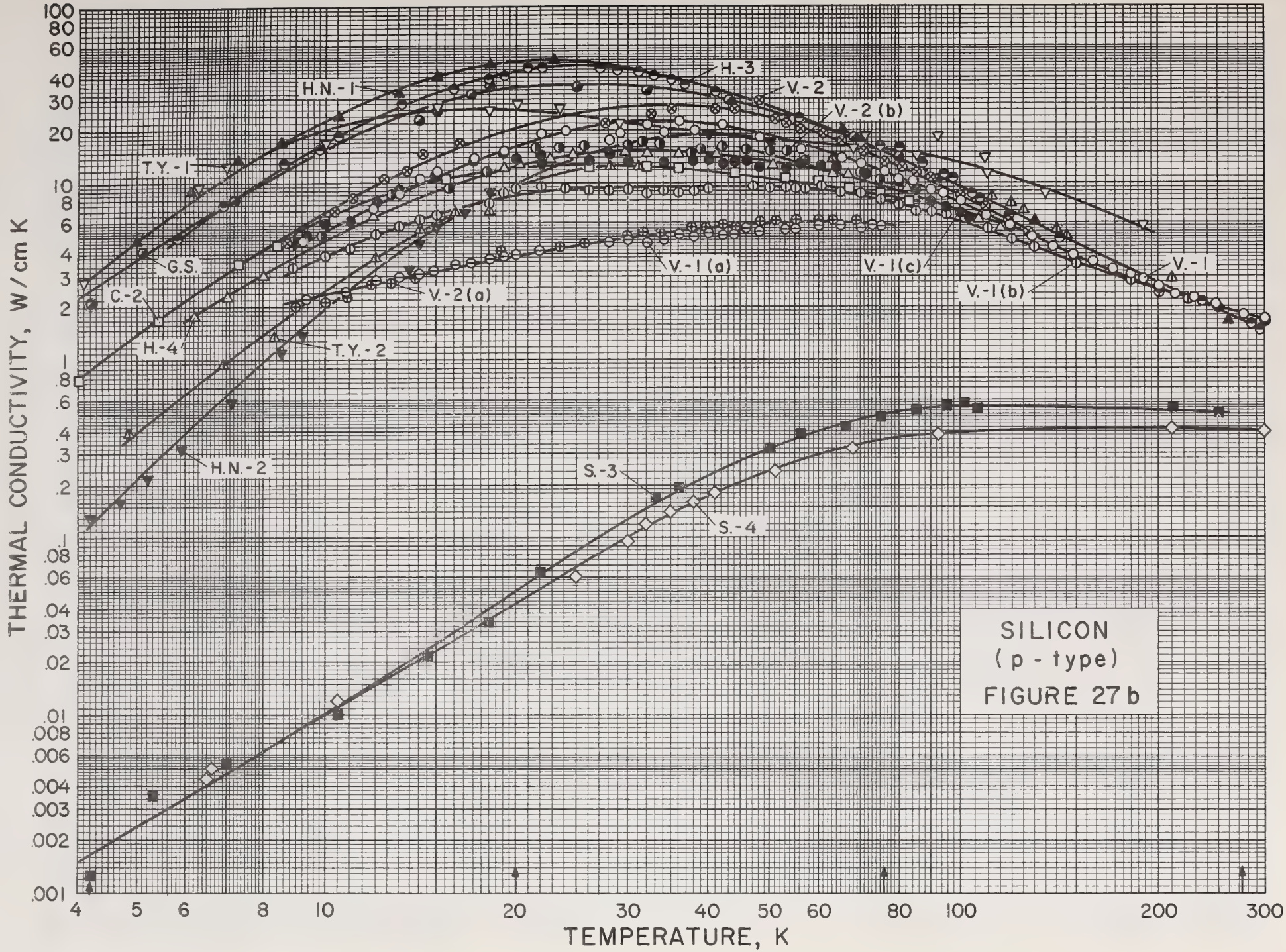
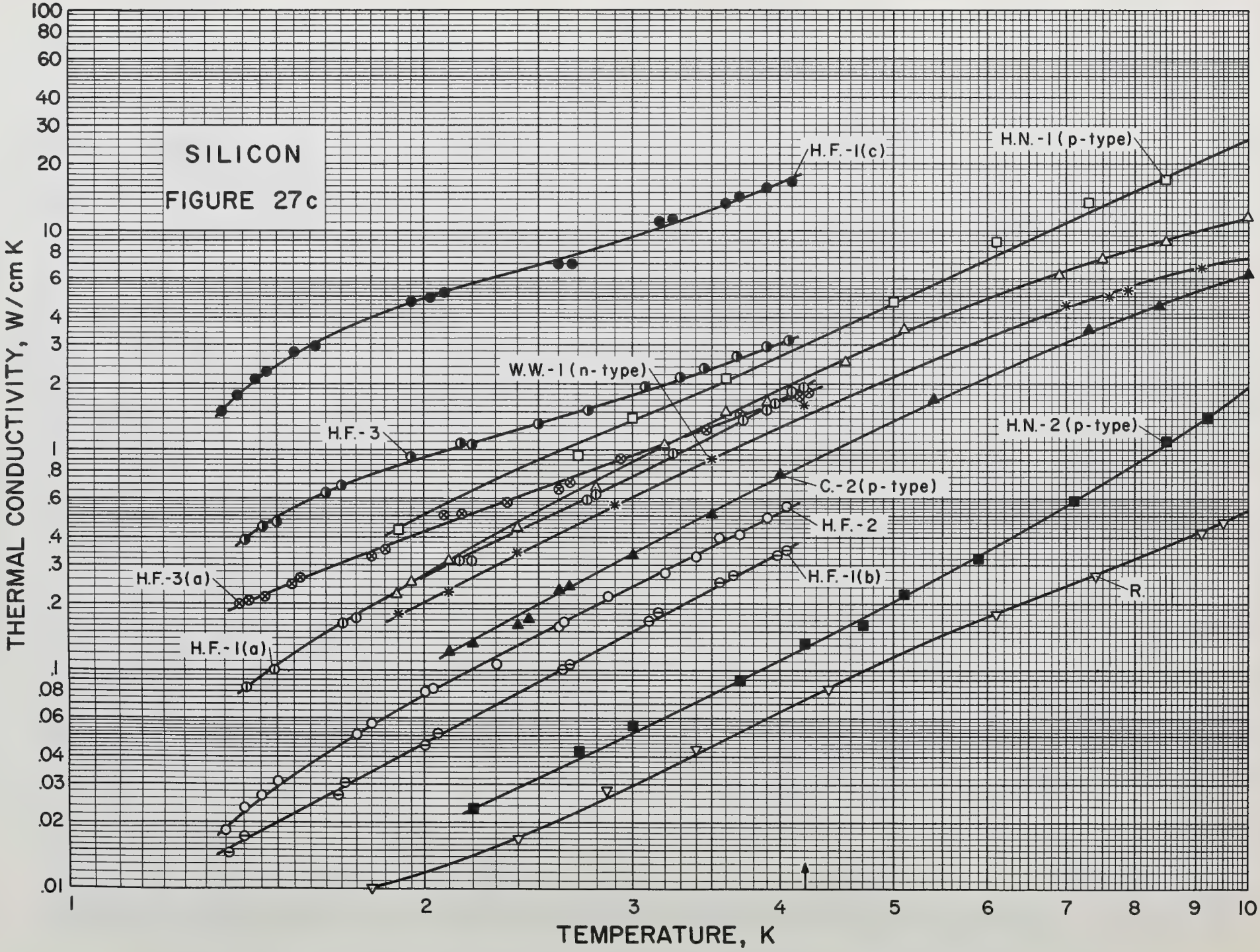
80
100
200
300


THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
H.N.-1
H.-3
V.-2
V.-2 (b)
T.Y.-1
G.S.
C.-2
H.-4
V.-1 (a)
V.-2 (a)
T.Y.-2
V.-1 (c)
V.-1
V.-1 (b)
H.N.-2
S.-3
S.-4
SILICON
(p - type)
FIGURE 27 b


SILICON
FIGURE 27c
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
H.F.-1(c)
H.N.-1 (p-type)
W.W.-1 (n-type)
H.F.-3
H.N.-2 (p-type)
C.-2(p-type)
H.F.-2
H.F.-1(b)
H.F.-3(a)
H.F.-1(a)
R.

SILICON

(See FIGURES 27a–27c)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	10^{-6} effective impurities; 0.005% (atomic) As.	"Filament cut from a crystal pulled in [100] direction". k = 1.48 at 0°C; k = 9 at 80K; k = 19.5 at 30K.	A-1; B-3; C-1; D-1(2); F-4; G-2.	G.W. Hull and T.H. Geballe (1954).
R.	Johnson, Matthey; "high purity".	Composed of fairly large crystallites, about 0.2 mm in size.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; O-3, 5; P-4.	H.M. Rosenberg (1954 b).
W.W.-1	Raytheon Manufacturing; carrier concentration probably $< 10^{16}/cm^3$.	Single crystal; n-type.	A-1; B-1; C-1; D-4(2); E-1,5; F-4; G-2; O-3; P-5.	G.K. White and S. B. Woods (1956b).
C-1,2	#1: high purity; no impurities added; carrier concentration of $5\times10^{14}/cm^3$ at room temperature. #2: 0.02% (atomic) Au; carrier concentration of $10^{15}/cm^3$ at room temperature.	Single crystals; pulled from the melt. Rod axis in [100] direction. #1: n-type. Sand blasted with 180-mesh SiC; heated in caustic-soda solution. Resistivity of 15-25Ω-cm at room temperature. #2: p-type; doped. Resistivity of 18-26Ω-cm at room temperature.	Same apparatus as Rosenberg (1954) and Hull and Geballe (1954) above; O-3, 5; P-5; Q-1, 3.	J.A. Carruthers, T.H. Geballe, H.M. Rosenberg, and J.M. Ziman (1957).
H-1, 2, 3, 4	#1: $< 10^{16}/cm^3$ oxygen; major additive P; carrier concentration of $4\times10^{13}/cm^3$ at room temperature. #2: $1.4\times10^{18}/cm^3$ oxygen; carrier concentration of $3.5\times10^{14}/cm^3$. #3: $< 10^{16}/cm^3$ oxygen; major additive B; carrier concentration of $4\times10^{14}/cm^3$. #4: $7\times10^{17}/cm^3$ oxygen; major additive B; carrier concentration of $4.8\times10^{15}/cm^3$.	Contain dissolved oxygen. #1: n-type; doped. #2: n-type. #3: p-type; doped. #4: p-type; doped. Resistivity of respective specimens at room temperature: 260; 12; 45.5; 3.0Ω-cm. Specimens #1-#3 have $10^4/cm^2$ dislocation density; #4 is "dislocation free". Three other specimens also measured, with intermediate values.	A-1; B-1; C-1; D-1(2); E-4; F-4; G-2; O-3; P-2, 3.	M.G. Holland (1960).

SILICON (cont'd)

(See FIGURES 27a–27b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
T.Y.-1,2	#1: Merck and Co.; $< 10^{17}/cm^3$ oxygen; $2\times10^{12}/cm^3$ B. #2 Texas Instruments: $2\times10^{17}/cm^3$ oxygen; $10^{15}/cm^3$ B.	Single crystals; doped; p-type. #1: resistivity at 0°C, of 2000Ω-cm. #2: resistivity at 0°C, of 7.2Ω-cm. Two other specimens also measured with intermediate values.	A-1; B-1; C-1; D-2, 3(2); E-5; F-4; G-3; O-3, 5; P-2, 3, 5, 8; Q-1.	J.C. Thompson and B.A. Younglove (1961); see also B.A. Younglove (1961).
H.N.-1,2	[illegible] $/cm^3$ B, $3.7\times10^{11}/cm^3$ P. #2: $4\times10^{16}/cm^3$ B; $< 10^{15}/cm^3$ P. Impurity inhomogeneities varies < 15% along specimens.	Single crystals; float-zoned; doped; p-type. Three other specimens measured with intermediate values over the complete temperature range; ten other specimens measured but not reported in detail.	A-1; B-1; C-1; D-1(2); E-4; F-4; G-2; O-5; P-2, 5.	M.G. Holland and L.J. Neuringer (1962).
A.V.(1)-1, 1(a), 1(b).	. . . . .	Single crystal; n-type; resistivity of 1Ω-cm. #1: specimen before irradiation. #1(a): specimen after irradiation of 1.2×10^{18} fast neutrons/cm^2 at 70 °C in 15 hrs. #1(b): specimen #1(a) after isochronal annealing for 1 hr at 133°C. Successive isochronal annealings at seven higher temperatures increased the thermal conductivity towards #1.	A-1; B-1; C-1; D-1, 3(2); F-4; G-3; O-3, 5; P-1, 2, 4.	H.J. Albany and M. Vandevyver (1963, 1965).
G.S.	"High purity"; oxygen and dislocation free.	Single crystal; p-type; grown by the pedestal method; growth direction was [111]. Vacancy clusters less than 1μ diameter. Resistivity of 2000 Ω-cm at room temperature.	A-1; B-1; C-1; D-1(2); E-1, 4; F-4; G-2; O-3; P-1, 5, 8.	C.J. Glassbrenner and G.A. Slack (1964).
S.-1, 2, 3, 4	#1: $2\times10^{19}/cm^3$ P. #2: $1.7\times10^{20}/cm^3$ P. #3: $3\times10^{20}/cm^3$ B. #4: $5\times10^{20}/cm^3$ B.	#1 and #2: synthetic single crystal, n-type; respective resistivity, at 300 K, of 0.028Ω-cm and 0.00067Ω-cm. #3: synthetic single crystal, p-type; resistivity of 4.5Ω-cm. #4: synthetic polycrystal, p-type; resistivity of 2.6Ω-cm. Low temperature values: #1 at 3 K, k = 0.0060; #3 at 2 K, k = 0.001.	A-1; B-1; C-1; D-1(2); E-1, 4; F-4; G-2; O-3; P-5, 8; Q-1.	G.A. Slack (1964).

SILICON (cont'd)
(See FIGURES 27a–27c)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
V.-1, 1(a), 1(b), 1(c), 2, 2(a), 2(b)	Merck and Co.; "high purity"; residual B; carrier concentration ~ 3×10^{12}/cm^3.	Single crystal; vacuum-floating-zone; p-type. Before bombardment, resistivity of $5\times10^3\Omega$-cm. Rod axis parallel [111] direction. #1: unirradiated; unannealed. Specimen #1 was irradiated at < 60 K in the [110] direction with a flux of 8×10^{18} e/cm^2 of 2 MeV electrons; then annealed for 15 minutes at the following temperatures: #1(a), 77 K; #1(b), 230 K; and #1(c), 410 K. #2: unirradiated; unannealed. Specimen #2 was irradiated identically to #1, then annealed for 15 minutes at the following temperatures: #2(a), 77 K; #2(b), 410 K. No change in conductivity with W-light illumination. Five other measurements for #1 at intermediate annealing temperatures; six other measurements for #2.	A-1; B-1; C-1; D-1(2); F-4; G-3; P-2, 4; Q-4.	F. L. Vook (1965 b).
Ho.	Knapic Electro-Physics. Carrier concentration of 5×10^{15}/cm^3.	Single crystal; n-type. Rod axis parallel to [111] direction.	A-6; B-1; C-1; D-1(2); E-1; F-4; G-3; O-3; P-8.	R. J. Holyer (1965).
A. V.(2)-1, 1(a), 1(b)	. . . . .	Single crystal; n-type. Resistivity of 0.35 Ω-cm. Grown by Czochrelski floating zone method; doped with P. Rod axis in [111] direction. #1: unirradiated. Specimen then irradiated at 30° C at fast-neutron doses of: #1(a), 1.1×10^{17} n/cm^2; #1(b), 3.4×10^{18} n/cm^2. Thermal neutron flux shielded. Two other measurements at intermediate irradiations with intermediate values.	A-1; B-1; C-1; D-1, 3(2); F-4; G-3; O-3; P-2, 5, 8.	H. J. Albany and M. Vandevyver (1967a); also Vandevyver and Albany (1965); also Vandevyver, P. Roubeau, and Albany (1966).

SILICON (cont'd)

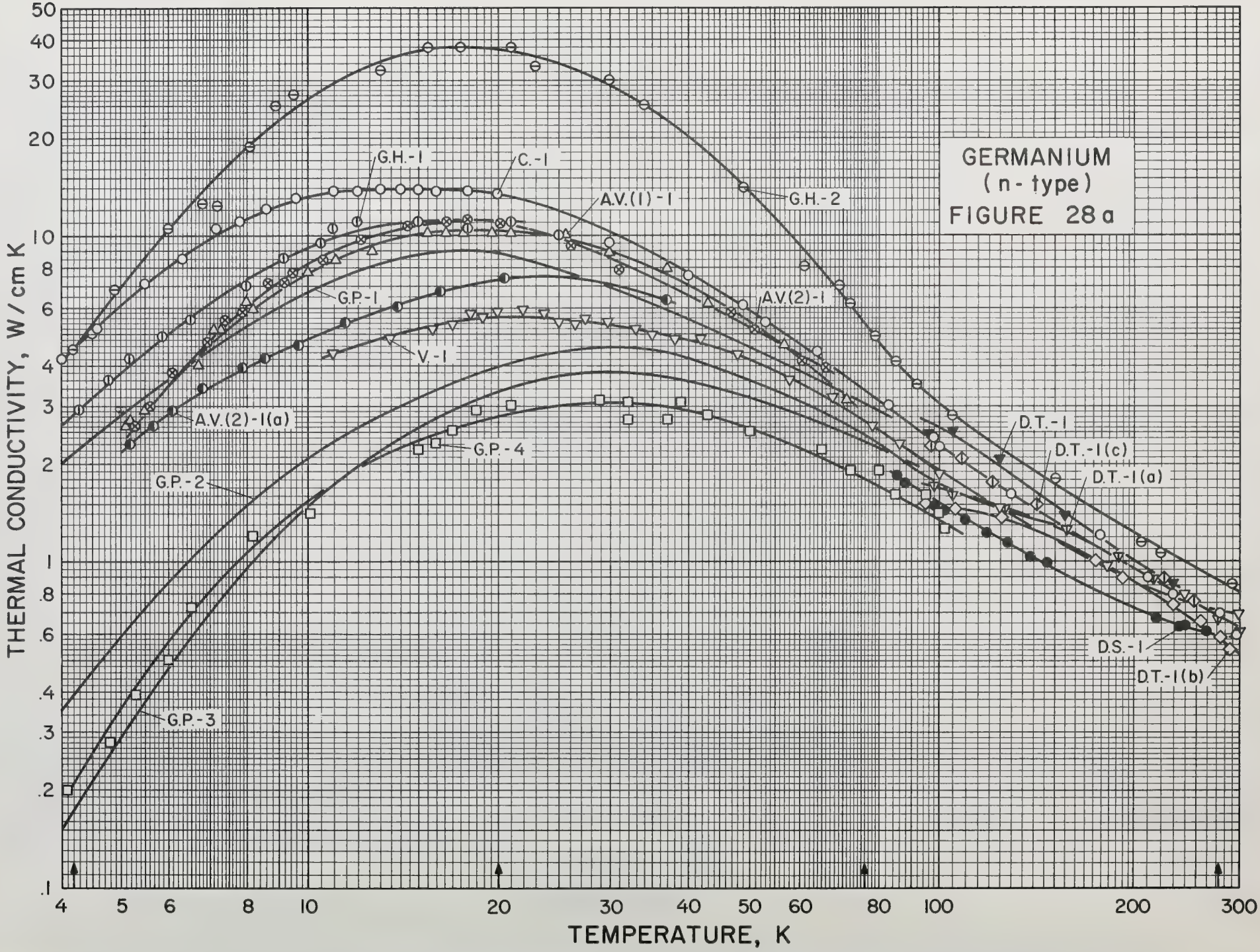
(See FIGURES 27a–27c)

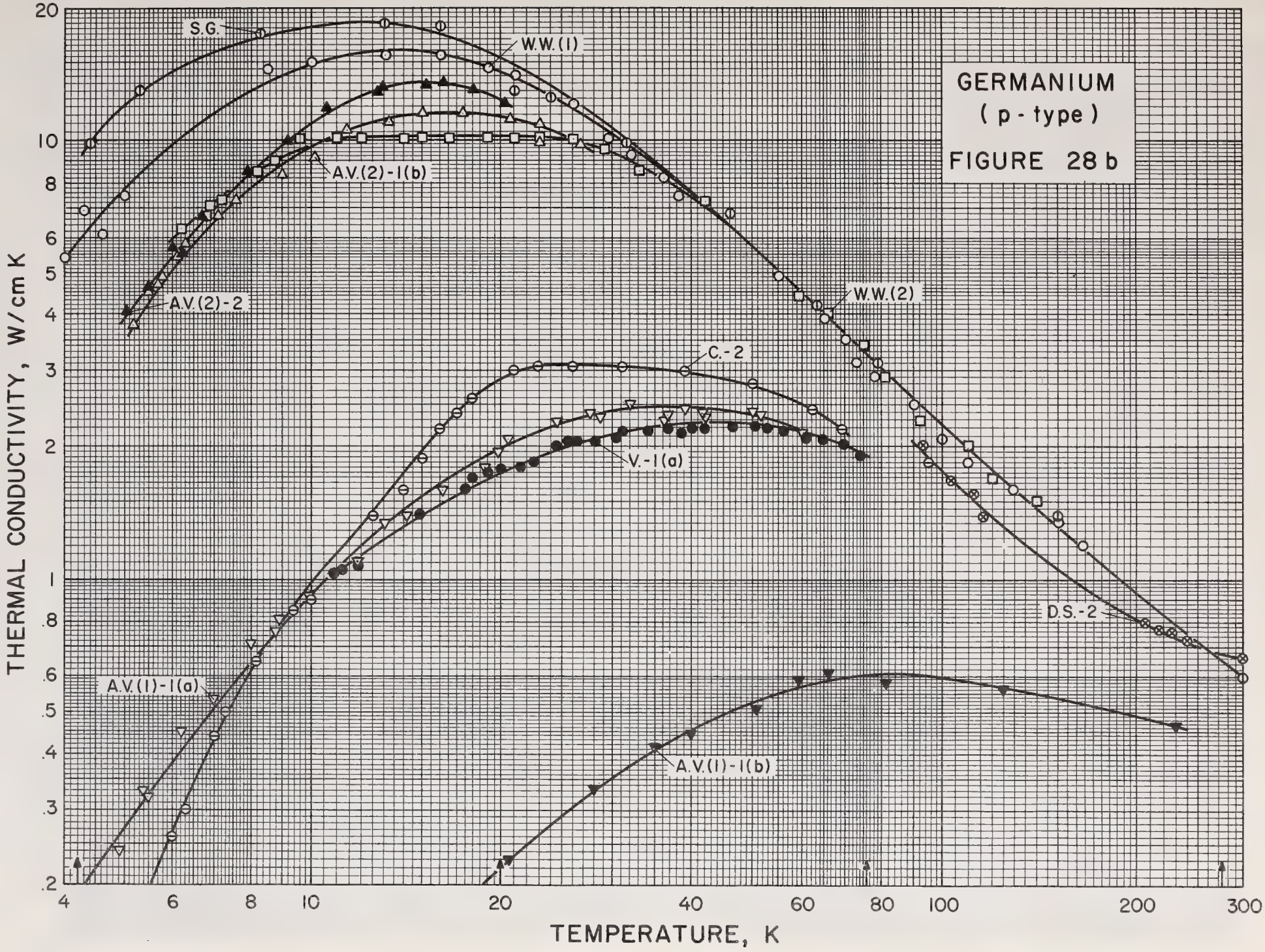
CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
F.	Semi-Elements; 24 ppm O_2; 12 ppm P; 5 ppm N_2; 4 ppm H_2; < 4 ppm Fe; < 1 ppm Ag, B, Be, Ca, Cr, Cu, K, Mn, Na, Ta, Th, Ti, U, W.	Large-grained polycrystal; n-type; density of 2.326 g/cm^3.	A-1; B-1; C-1; D-1(2); E-1; F-1; G-2; O-3; P-2, 8; R-3; S-1, 2.	W. Fulkerson, J.P. Moore, R. K. Williams, R. S. Graves, and D.L. McElroy (1968).
H.F.-1(a), 1(b), 1(c), 2	"High purity". #1(a), #1(b), and #1(c): Knapic Electro-Physics. #2: Futurecraft Corp. Both specimens free of large concentrations of O_2. #3: Semi-elements, Inc.	#1(a), #1(b), and #1(c): p-type; room temperature resistivity of 195Ω-cm. Grown in the [111] direction. Average dislocation density of 750 pits/cm^2. Square cross-section, rough-surfaced rods with rod widths of 2.9 and 0.52 mm, and rectangular cross-section with a width ratio of 9:1, respectively. Seven additional square and three rectangular specimens were measured. Surfaces were lapped with 5, 10, 10μ Al_2O_3 powder, respectively. Seven additional rough-surfaced [100] specimens were measured. #2: n-type; room temperature resistivity of 500Ω-cm. Grown in the [100] direction. Specimen had polished surface termed "very smooth". Prepared by mechanical polishing with 6μ and 1μ diamond compound, followed by Lustrox polishing. Square cross-section of 0.88 mm width. Fifteen additional polished-surface and six chemically etched specimens were measured. #3: n-type; room temperature resistivity of 3000 Ω-cm. Rod axis in [100] direction. Same mechanical polishing treatment as #2. #3(a): bombarded with Ar at a pressure of 15×10^{-3} Torr for 20 minutes with a current density of 50μ-Amps/cm^2 and a voltage of 500 V.	A-1; B-1; C-1; D-2(2); E-5; F-4; G-2; O-5; P-5.	W.S. Hurst and D. R. Frankl (1969).
. . . . .	. . . . .	Measured the thermal conductivity of n-type silicon doped with As, Sb, or P in the temperature range 4-290 K.	. . . . .	M. E. Brinson and W. Dunstan (1970).

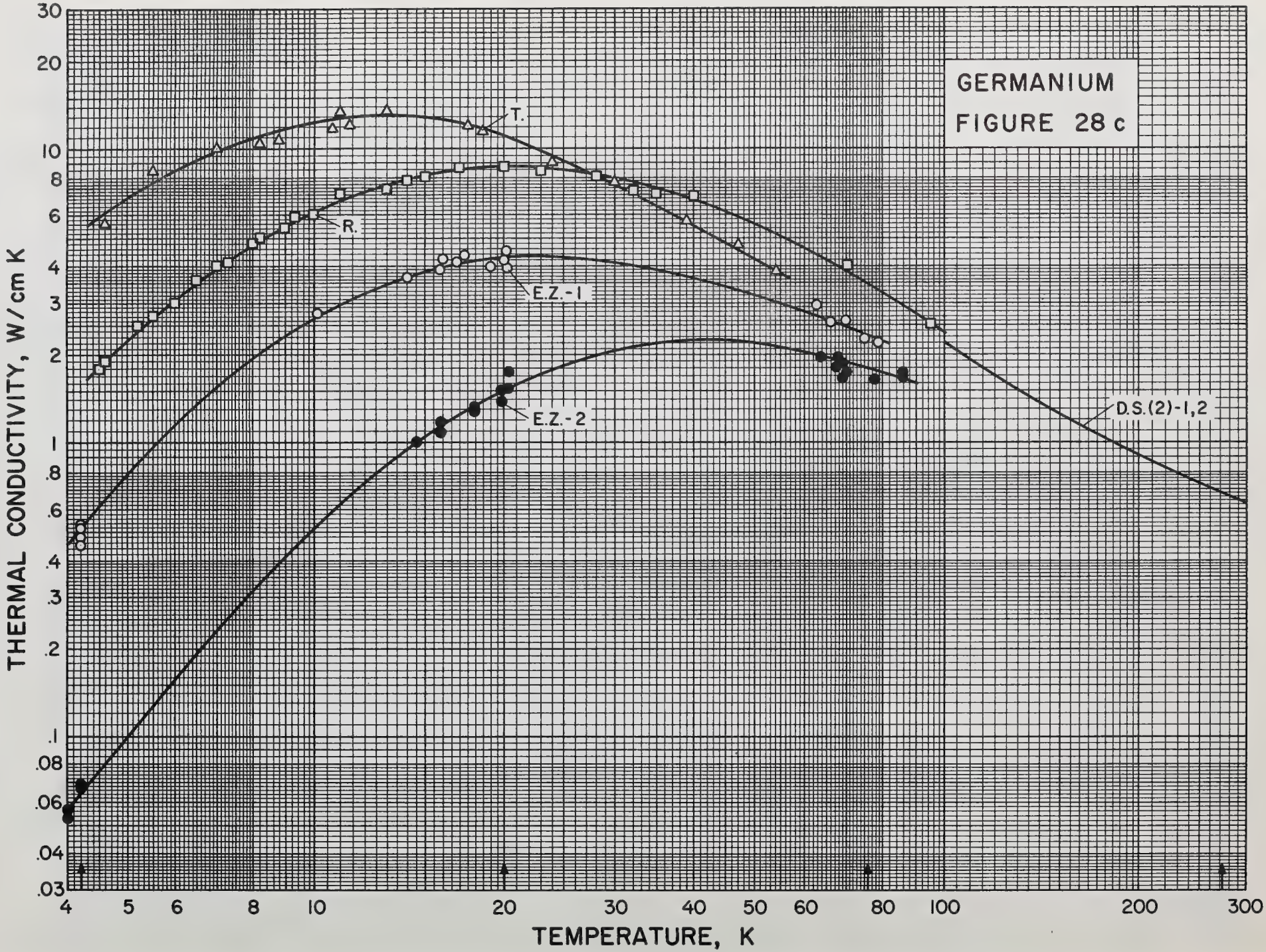
SILICON (cont'd)

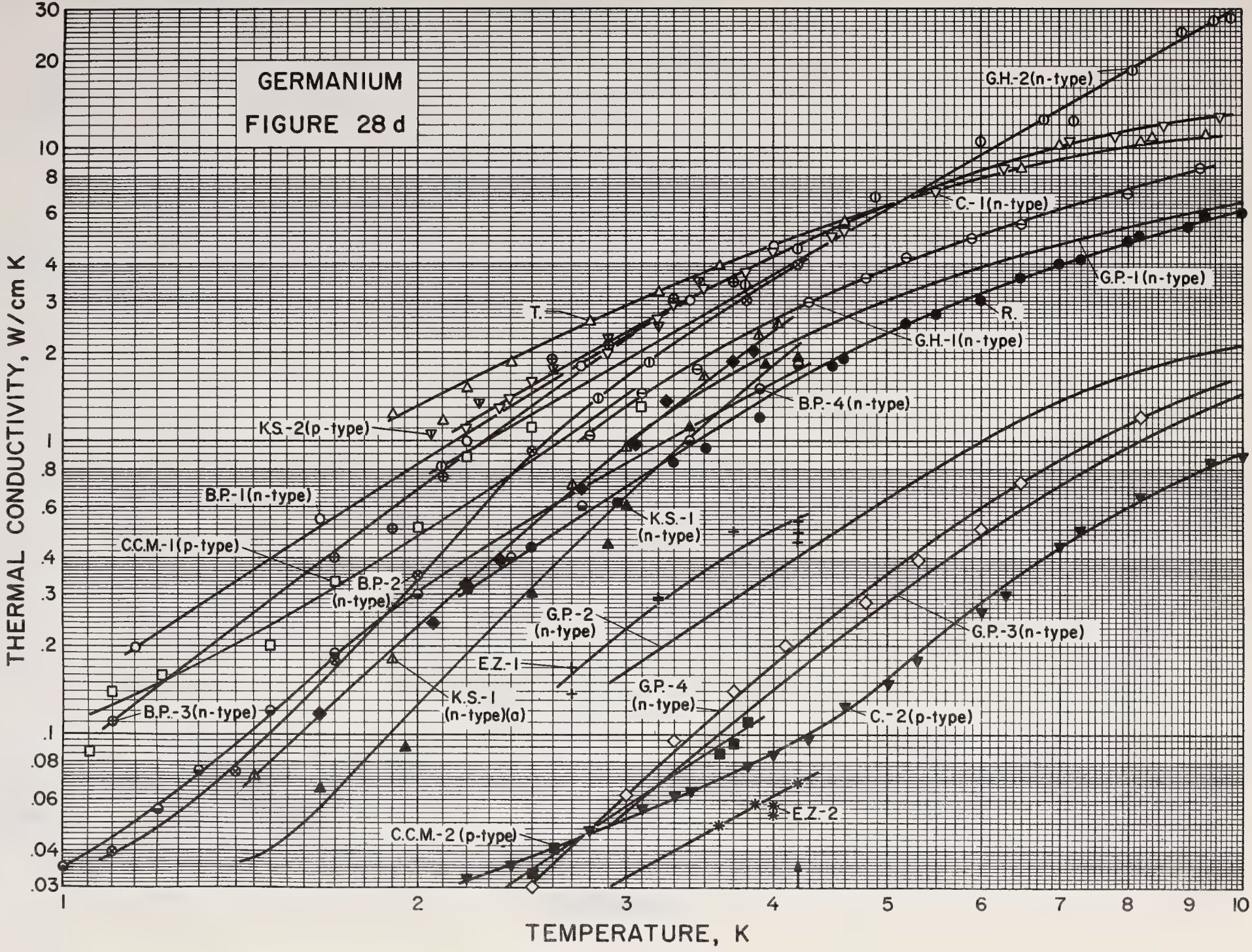
(See FIGURES 27a–27c)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	Measured the thermal conductivity of 7 specimens of n and p-type silicon, with no irradiation and irradiated with fast neutrons with flux up to 6×10^{17} n/cm^2; effective annealing was studied also.	. . . . .	P. Seyfert (1970).


GERMANIUM
(n-type)
FIGURE 28a
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
50
40
30
20
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
4
5
6
8
10
20
30
40
50
60
80
100
200
300
G.H.-1
C.-1
A.V.(1)-1
G.H.-2
G.P.-1
A.V.(2)-1
V.-1
A.V.(2)-1(a)
G.P.-4
D.T.-1
D.T.-1(c)
D.T.-1(a)
G.P.-2
G.P.-3
D.S.-1
D.T.-1(b)


GERMANIUM
(p - type)
FIGURE 28 b
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
S.G.
W.W.(1)
A.V.(2)-1(b)
A.V.(2)-2
W.W.(2)
C.-2
V.-1(a)
D.S.-2
A.V.(1)-1(a)
A.V.(1)-1(b)
20
10
8
6
5
4
3
2
1
.8
.6
.5
.4
.3
.2
4
6
8
10
20
40
60
80
100
200
300


GERMANIUM
FIGURE 28 c
T.
R.
E.Z.-1
E.Z.-2
D.S.(2)-1,2
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
30
20
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
4
5
6
8
10
20
30
40
50
60
80
100
200
300


GERMANIUM
FIGURE 28 d
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
30
20
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
1
2
3
4
5
6
7
8
9
10
G.H.-2(n-type)
C.-1(n-type)
G.P.-1(n-type)
T.
R.
G.H.-1(n-type)
B.P.-4(n-type)
K.S.-2(p-type)
B.P.-1(n-type)
K.S.-1
(n-type)
C.C.M.-1(p-type)
B.P.-2
(n-type)
G.P.-2
(n-type)
G.P.-3(n-type)
E.Z.-1
G.P.-4
(n-type)
K.S.-1
(n-type)(a)
B.P.-3(n-type)
C.-2(p-type)
E.Z.-2
C.C.M.-2(p-type)

GERMANIUM

(See FIGURES 28a–28d)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
E.Z.-1,2	#1: "high purity". #2: 0.006% (atomic) Aℓ.	Cast in vacuum in a graphite crucible lowered through a vacuum furnace.	A-1; B-1; C-1; D-4(2); F-4; G-3; O-3; P-2,4.	I. Estermann and J.E. Zimmerman (1951).
. . . . .	"High purity".	Single crystal; n-type; rod axis parallel to [100] crystal axis. Resistivity about 10Ω-cm. k = 0.59 at 25°C.	A-6; B-2; C-1; G-3.	A. Grieco and H.C. Montgomery (1952).
R.	"High degree of purity".	Single crystal; room temperature resistivity of 60Ω-cm.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; O-3,5; P-4.	H.M. Rosenberg (1954 b).
W.W.(1)	"High purity"; carrier concentration ~ $7.7\times10^{14}/cm^3$.	Single crystal; p-type. Resistivity at 22°C of 31Ω-cm.	A-1; B-1; C-1; D-4(2); E-1,5; F-4; G-1; O-3; P-4.	G.K. White and S.B. Woods (1955).
. . . . .	Westinghouse Research Laboratories; "high purity".	n-type; resistivity of 40Ω-cm; rod axis parallel to [100] crystal axis. k = 0.607 at 5°C; k = 0.588 at 21°C.	A-6; B-2; C-1; D-1(3); G-3.	K.A. McCarthy and S.S. Ballard (1955).
W.W.(2)	"High purity".	#1: polycrystalline; p-type; resistivity at 22°C of 30Ω-cm. Specimen #1 was then cleaned with fine emery, concentrated nitric acid, hydrogen peroxide, potassium cyanide solution, and de-ionized water, then annealed in helium atmosphere for 3 hours at 550°C, cooled slowly, then remeasured; thermal conductivity values are on same curve as #1.	A-1; B-1; C-1; D-4(2); E-1,5; F-4; G-2; O-3; P-4,5.	G.K. White and S.B. Woods (1956b).
C.-1,2	#1: "highly purified"; room temperature carrier concentration of $10^{13}/cm^3$. #2: Ga dopant; carrier concentration of $10^{19}/cm^3$.	#1: n-type. Grown by zone process; surface sand-blasted with 180-mesh SiC. Room temperature resistivity of 36-42Ω-cm; inhomogenuities of 16% by resistivity measurements. Rod axis parallel to [100] crystal axis. #2: p-type. Pulled from the melt; surface sand blasted. Resistivity of $1.8\text{-}3.5\times10^{-3}$Ω-cm; inhomogenuities of 50%. Rod axis parallel to [100] crystal axis. Six other specimens, with intermediate carrier levels and of different types, were also measured, with intermediate values.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; O-5; P-2,5,8; Q-3.	J.A. Carruthers, T.H. Geballe, H.M. Rosenberg, and J.M. Ziman (1957).

GERMANIUM (cont'd)
(See FIGURES 28a–28d)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
D.S.-1, 2	#2: Ga dopant.	#1: n-type. Room temperature resistivity of 2.84Ω-cm. #2: p-type (produced thermally from an n-type specimen). Resistivity of 1.6 Ω-cm. Six other specimens measured.	A-1; B-1; C-1; D-1(2); F-4; G-3; O-3; P-4, 5; S-2.	E.D. Devyatkova and I.A. Smirnov (1957).
G.H.-1, 2	#1: normal isotopic concentration. #2: Union Carbide Nuclear Co.; "very high purity"; isotopic concentrations of 95.8% Ge^{74}; 1.56% Ge^{73}; 1.135% Ge^{72}; 0.818% Ge^{76}; 0.691% Ge^{78} (atomic); excess donor concentration ~ $1.2 \times 10^{13}/cm^3$.	#1: control specimen. #2: single crystal; n-type. Zone refined. Rod axis parallel to [100] crystal axis. Enriched Ge^{74}. Etch-pitch counts of 10^4 dislocations/cm^2.	A-1; B-3; C-1; D-1, 2(2); F-4; G-2; O-3; P-5, 8.	T.H. Geballe and G.W. Hull (1958).
. . . . .	. . . . .	Determined the thermal conductivity of single crystal, p-type, [111] oriented Ge between 77 and 300K in conjunction with experiments on the volume gradient thermal EMF.	. . . . .	P.I. Baranskii and N.S. Konopliasova (1958).
. . . . .	. . . . .	Reported results on six n- and p-type, Sb or Ga doped, specimens with resistivities of 4.3×10^{-3} - 60Ω-cm. Results reanalyzed and conclusions changed in Devyatkova and Smirnov (1962).	. . . . .	E.D. Devyatkova and I.A. Smirnov (1960).
S.G.	"Very pure". $10^{14}/cm^3$ residual Cu atoms.	Single crystal; p-type. Zone melted. Room temperature resistivity of 30Ω-cm. Average crystallite size of 0.2 cm. Dislocation density of $3 \times 10^3/cm^2$. Crystal cut on a diamond wheel and moderately etched to provide a diffuse reflecting surface.	A-1; B-1; C-1; D-1(2); E-1,4; F-4; G-2; O-3, 5; P-5, 8.	G.A. Slack and C. Glassbrenner (1960); also C. Glassbrenner and G.A. Slack (1964).
T.	RCA Research Laboratories; 10 ppm Al and Cu; 5 ppm Mg.	Smooth shiny surface; etched in CP-4.	A-1; B-1; C-1; D-3(2); F-4; G-2; O-3; P-2, 4, 5, 8; Q-1.	A.M. Toxen (1961).

GERMANIUM (cont'd)
(See FIGURES 28a–28d)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
K.S.-1, 1(a), 2	#1: Sb dopant; carrier concentration of $2\times10^{16}/cm^3$.	Single crystals; grown by Czochralski method; cut with a diamont wheel. Inhomogenuities < 10% as determined by Hall coefficients. #1: n-type. Resistivity at 27°C of 0.13Ω-cm. Rod axis parallel to [110] crystal axis. #1(a): specimen #1 had a tensile stress of 1.45×10^8 dynes/cm^2. #2: p-type. Resistivity of 47Ω-cm. Rod axis parallel to [110] crystal axis. An applied tensile stress of 1.27×10^8 dynes/cm^2 had a result of a 15% decrease on the thermal conductivity. Four other n-type specimens, each unstressed and stressed, of [100], [110], and [111] orientation, resistivities from 0.12-31Ω-cm, doped with Sb or As, were measured. Graph of thermal conductivity as a function of tensile stress.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-2; O-6; P-2, 5, 9; Q-1.	R.W. Keyes and R. J. Sladek (1962).
C.C.M.-1, 2; also see FIGURE 74	Bell Telephone Laboratories. #1: In dopant; carrier concentration of $1.9\times10^{14}/cm^3$. #2: Ga dopant; carrier concentration of $2\times10^{18}/cm^3$.	Single crystals; p-type. Surfaces sand blasted. #1: grown by zone process. Room temperature resistivity of 20-22Ω-cm; inhomogenuities of 10% by resistivity measurements. Rod axis parallel to [111] crystal axis. #2: grown by Czochralski method. Resistivity of $6\text{-}12\times10^{-3}$ Ω-cm; inhomogenuities of 50%. Rod axis parallel to [100] crystal axis. Six other specimens of n- and p-type, in the [110] and [111] direction, resistivities of 2×10^{-3}-42Ω-cm, undoped and doped with In or Ga, were also measured. Also measured below 1 K.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-2; O-5; P-2, 4; Q-1, 3; S-1.	J.A. Carruthers, J.F. Cochran, and K. Mendelssohn (1962).

GERMANIUM (cont'd)

(See FIGURES 28a–28d)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
D.S.(2)-1, 2	O_2, $\sim 10^{16}/cm^3$ (by optical absorption at 11.6μ).	Prepared from melt in H_2 atmosphere. Doped during growth. #1: four different specimens gave the same results. Two n-type doped with Sb, resistivities at 27°C of $2.27\times10^{-2}\Omega$-cm; two p-type doped with Ga, resistivities of 1.54×10^{-1} and $1.55\times10^{-1}\Omega$-cm. #2: four different specimens gave the same results. Two n-type doped with Sb, resistivities of 15.1 and 13.9 Ω-cm; two p-type doped with Ga, resistivities of 25.4 and 26.0Ω-cm.	A-1; B-1; C-1; D-1(2); F-4; G-3; O-3; P-2, 5.	E.D. Devyatkova and I.A. Smirnov (1962).
D.T.-1, 1(a), 1(b), 1(c)	. . . . .	#1: n-type. Specimen then irradiated by fast-neutron doses at total fluxes of: #1(a), 6×10^{17}n/cm^2; #1(b), 1.2×10^{18}n/cm^2. #1(c): then annealed for 2 hrs.at 260°C.	A-6; B-1; C-1; D-1(2); F-4; G-3; O-3; P-2; S-1, 2.	N. van Dong and P. N. Tung (1963).
V.-1, 1(a)	Eagle-Picher Co.; "high purity". Carrier concentration of $\sim 10^{14}/cm^3$.	#1: single crystal; n-type. Resistivity of 50Ω-cm. Rod axis parallel to [110] crystal axis. #1(a): irradiated, in the [111] direction, at a total flux of 1.01×10^{18} 2-Mev electrons/cm^2, at 70K or lower; p-type; then annealed for 15 minutes at 77K. Six other annealings at temperatures up to 405K resulted in thermal conductivity values approaching the curve for #1. Another "essentially equivalent" specimen was also similarly irradiated at a flux of 3.4×10^{18} and annealed. Also measured the effect of illumination by W and white-light on the specimens.	A-1; B-1; C-1; D-1(2); F-4; G-3; O-3; P-2, 9; Q-1.	F.L. Vook (1965 a).

GERMANIUM (cont'd)

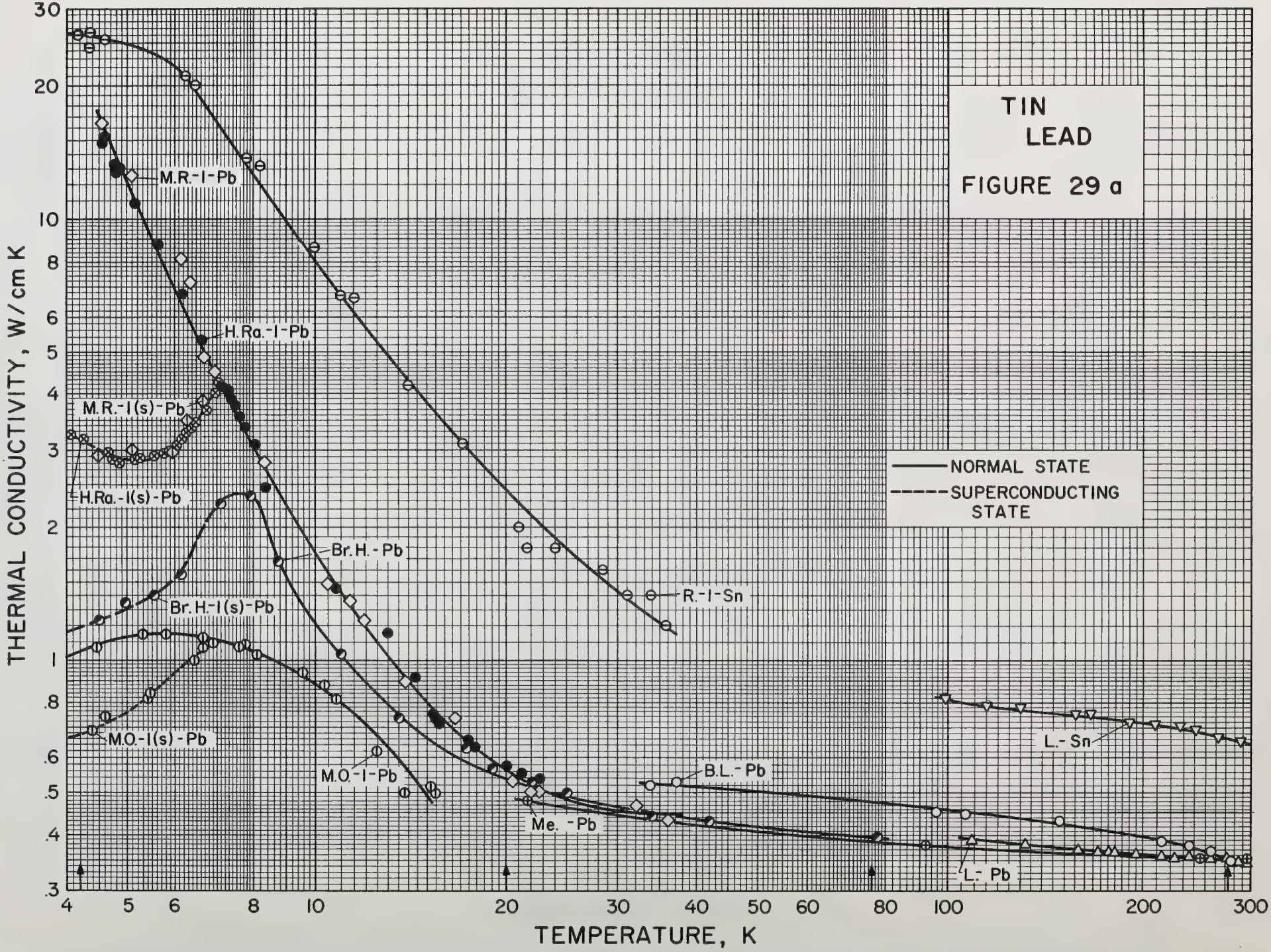
(See FIGURES 28a–28d)

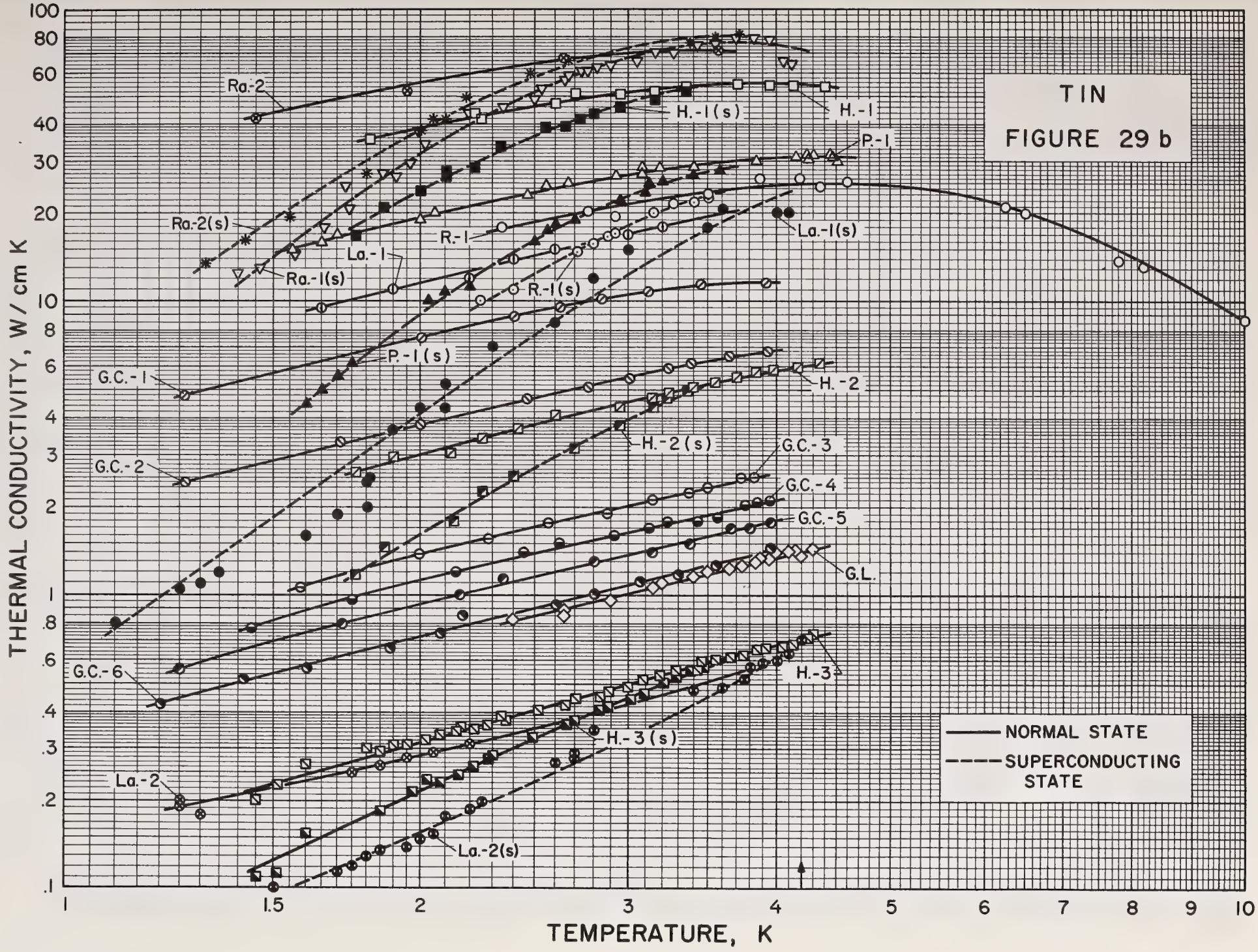
CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
G.P.-1, 2, 3, 4	#2: compensated; other specimens uncompensated. #1: Sb dopant; dopant concentration of $6.1\times10^{15}/cm^3$. #2: Sb Ga dopant; more donor than acceptor concentration of $1.5\times10^{17}/cm^3$. #3: Sb dopant; dopant concentration of $2.5\times10^{18}/cm^3$. #4: As dopant; carrier concentration of $8.8\times10^{17}/cm^3$.	Single crystals; n-type. Doped. Grown by the Czochralski technique: cut transverse to growth axis; ground surfaces. #1: rod axis parallel to [111] crystal axis. #2-#4: rod axis parallel to [100] crystal axis. Respective room temperature resistivities of 398.8, 61.87 (at 127°C) 3.14, and 6.584Ω-cm. Three other Sb-doped specimens, Five As-doped specimens, and two Sb Ga-doped specimens.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-2; O-2, 3; P-2, 5, 9; Q-1, 3; S-1, 2.	J.F. Goff and N. Pearlman (1965).
A.V.(1)-1, 1(a), 1(b)	Sb dopant.	Single crystals; n-type. Resistivity of 0.10Ω-cm. Grown by the Czochralski technique; rod axis parallel to [111] crystal axis. #1: unirradiated. Specimen then irradiated, at about 30°C, at fast-neutron doses of: #1(a), 1.1×10^{17}; #1(b), 3.4×10^{18} n/cm². Also irradiated at 2.5×10^{17} and 1.7×10^{18} n/cm², resulting in intermediate thermal conductivity values. Irradiation resulted in specimen being converted to p-type.	A-1; B-1; C-1; D-1, 3(2); F-4; G-3; O-3; P-2, 5, 8, 9; Q-1.	H.J. Albany and M. Vandevyver (1967a); also M. Vandevyver and H.J. Albany (1965); also M. Vandevyver, P. Roubeau, and H.J. Albany (1966).
A.V.(2)-1, 1(a), 1(b), 2	#1: Sb dopant. #2: In dopant.	Single crystals. Grown by Czochralski technique. Rod axis parallel to [111] crystal axis. #1: n-type. Resistivity of 0.10Ω-cm. Unirradiated. Specimen then irradiated, at about 40°C, with a beam current of 35μ-amps, at 4-MeV electron doses: #1(a), 1.3×10^{17}; #1(b), 1.6×10^{18} electrons/cm². Irradiation resulted in specimen #1(b) being converted to p-type. Also irradiated at 5.2×10^{17} electrons/cm², resulting in intermediate values. #2: p-type. Resistivity of 1.2Ω-cm. Irradiation, identical to #1, at 1.3×10^{17}, 2.6×10^{17}, 6.5×10^{17}, and 1.7×10^{18} electrons/cm² resulted in "no noticeable change" in thermal conductivity.	A-1; B-1; C-1; D-1, 3(2); F-4; G-3; O-3, 5; P-9; Q-3.	H.J. Albany and M. Vandevyver (1967b).

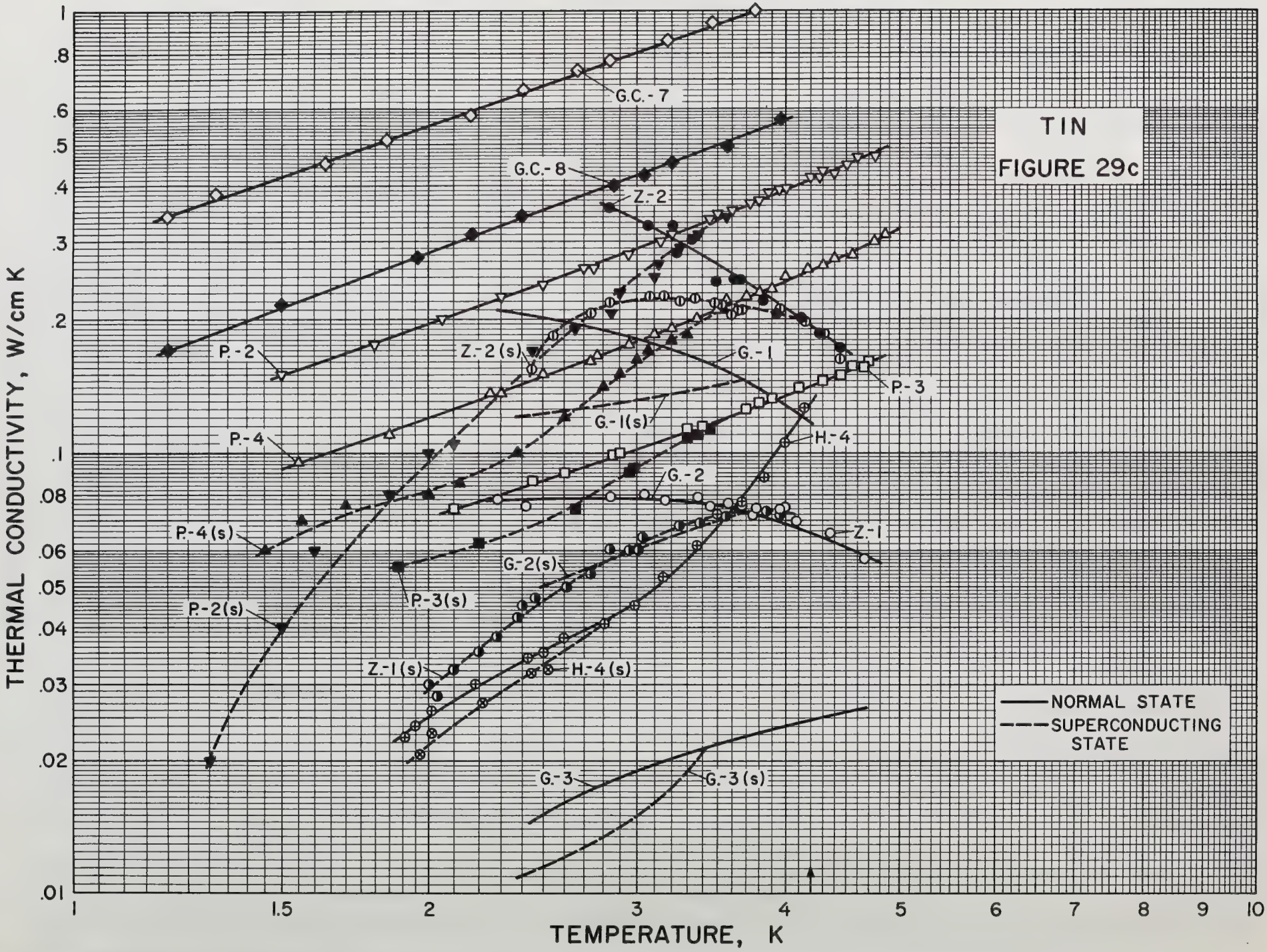
GERMANIUM (cont'd)

(See FIGURES 28a–28d)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
B.P.-1, 2, 3, 4; also see FIGURE 74	#1: impurity concentration of $5.4\times10^{13}/cm^3$. #2: Sb dopant; dopant concentration of $3.6\times10^{15}/cm^3$. #3: As dopant; dopant concentration of $5.3\times10^{15}/cm^3$. #4: P dopant; dopant concentration of $2.6\times10^{16}/cm^3$.	n-type. Rod axis parallel to [100] crystal axis, perpendicular to growth axis. Also measured below 1 K.	A-1; B-1; C-1; D-3(2); E-5, 6; F-4; G-3; P-5, 9; Q-3.	B.L. Bird and N. Pearlman (1968).


TIN
LEAD
FIGURE 29 a
NORMAL STATE
SUPERCONDUCTING STATE
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
M.R.-I-Pb
H.Ra.-I-Pb
M.R.-I(s)-Pb
H.Ra.-I(s)-Pb
Br.H.-Pb
Br.H.-I(s)-Pb
M.O.-I(s)-Pb
M.O.-I-Pb
Me.-Pb
R.-I-Sn
L.-Sn
B.L.-Pb
L.-Pb
30
20
10
8
6
5
4
3
2
1
.8
.6
.5
.4
.3
4
5
6
8
10
20
30
40
50
60
80
100
200
300


TIN
FIGURE 29 b
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
100
80
60
40
30
20
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
1
1.5
2
3
4
5
6
7
8
9
10
Ra.-2
Ra.-2(s)
Ra.-1(s)
La.-1
R.-1
R.-1(s)
H.-1(s)
H.-1
P.-1
La.-1(s)
P.-1(s)
G.C.-1
H.-2
H.-2(s)
G.C.-2
G.C.-3
G.C.-4
G.C.-5
G.L.
G.C.-6
H.-3
H.-3(s)
La.-2
La.-2(s)
NORMAL STATE
SUPERCONDUCTING STATE


TIN
FIGURE 29c
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
1
.8
.6
.5
.4
.3
.2
.1
.08
.06
.05
.04
.03
.02
.01
1
1.5
2
3
4
5
6
7
8
9
10
G.C.-7
G.C.-8
Z.-2
P.-2
Z.-2(s)
G.-1
P.-3
G.-1(s)
P.-4
H.-4
G.-2
P.-4(s)
Z.-1
G.-2(s)
P.-3(s)
P.-2(s)
Z.-1(s)
H.-4(s)
G.-3
G.-3(s)
NORMAL STATE
SUPERCONDUCTING STATE

TIN
(See FIGURES 29a–29c)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	"Pure".	k = 0.64 at 0°C.	A-5; B-1; C-1; D-7(9); F-5; G-3; S-1, 3, 5.	L. Lorenz (1881 a).
. . . . .	Kahlbaum; "pure"; < 0.03% Pb.	Cast. k = 0.61 at 18°C. Specific density of 7.28.	A-4; B-1; C-2, 3; D-1(3); E-1; F-4; G-3; S-1, 2, 3, 5.	W. Jaeger and H. Diesselhorst (1900).
L.-Sn	Kahlbaum; "pure".	Lathe turned from a bar. Specific density of 7.28 at 21°C.	A-1; B-1; C-1; D-2(2); E-2; F-4; G-3; L-1; S-1, 5.	C.H. Lees (1908).
. . . . .	. . . . .	Measured the relative change in conductivity at low temperatures; absolute values not given.	. . . . .	W.J. de Haas, S. Aoyama, and H. Bremmer (1931); also W.J. de Haas and H. Bremmer (1931).
H.-1, 1(s), 2, 2(s), 3, 3(s), 4, 4(s).	Johnson, Matthey 2356. #1: 0.004% impurity. #2: 0.033% Hg added. #3: 0.33% Hg added. #4: 4.1% Hg added (weight).	#1 - #3: homogeneous solid solutions, few large crystals. #4: two-phase, few large crystals. Measured in both the normal and superconducting (s) states. T_c = 2.21 K. Graph of the ratio of the thermal conductivity of the superconducting and normal states as a function of reduced temperature. Graph of thermal conductivity as a function of magnetic field to 0.15 T.	A-1; B-1; C-1; D-4(2); E-5; F-4; G-2; L-1, 2; M-1, 2; N-3; P-2, 4; Q-1; S-1.	J.K. Hulm (1949, 1950).
. . . . .	. . . . .	Measured ratio of superconductive to normal thermal conductivity; $k_s/k_n \simeq 1/40$ at 0.65 K.	. . . . .	C.V. Heer and J.G. Daunt (1949).
Ra.-1(s), 2, 2(s)	Champur; 99.992% pure; RRR = 17,000.	Single crystals; melted in vacuum, crystallized and etched on the surface. Rod axis inclined 85° to the tetragonal crystal axis. #1(s): Measured in zero field. #2, 2(s): measured in both the normal (in a longitudinal field of 0.051 T) and superconducting (s) states. Graph of the ratio of the thermal conductivity of the superconducting and normal states as a function of reduced temperature.	A-1; B-1; C-1; D-2(2); E-2, 5; F-4; G-3; M-1; N-3; P-5.	A. Rademakers (1949).

TIN (cont'd)

(See FIGURES 29a–29c)

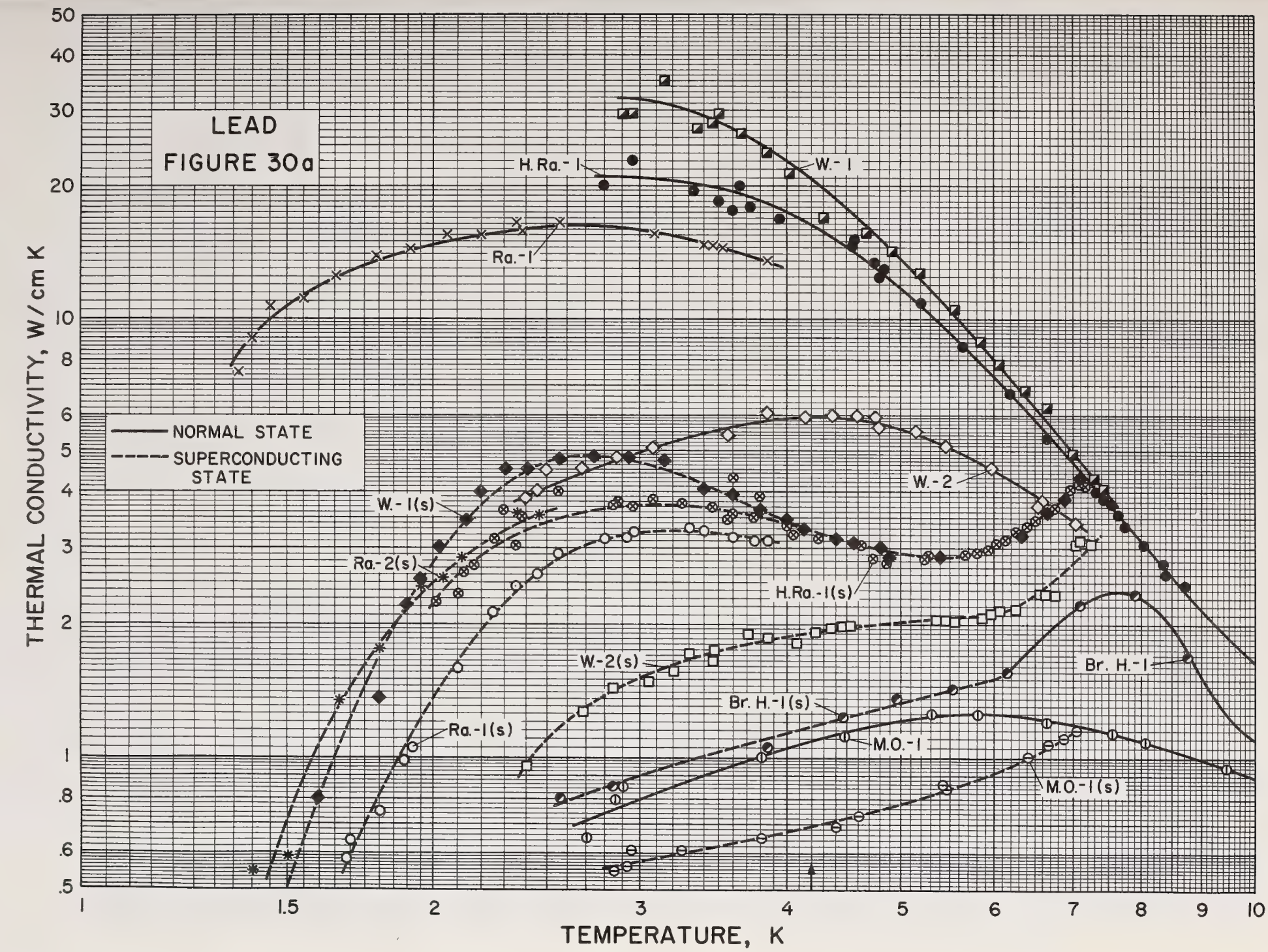
CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	Johnson, Matthey 2356; 99.996 % pure. Also a specimen of 0.134% Bi.	Measured thermal conductivity in normal, intermediate, and superconducting states as a function of transverse magnetic fields up to 0.03 T. Graphs of the thermal conductivity as a function of the transverse magnetic fields up to 0.03 T.	. . . . .	D.P. Detwiler and H.A. Fairbank (1952 a, b).
. . . . .	. . . . .	Graph of thermal conductivity as a function of transverse and longitudinal magnetic fields up to 0.4 T from 2.4 to 4.4 K.	. . . . .	K. Mendelssohn and H.M. Rosenberg (1953).
See FIGURE 74	. . . . .	Measured superconducting state below 1 K.	. . . . .	K. Mendelssohn and C.A. Renton (1953).
See FIGURE 74	. . . . .	Measured superconducting state below 1 K.	. . . . .	B.B. Goodman (1953).
R.-1, 1(s)-Sn	Johnson, Matthey; 99.997% pure.	Single crystal. Measured both normal and superconducting (s) states. T_c = 3.69 K.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1; N-3.	H.M. Rosenberg (1955).
La.-1, 1(s), 2, 2(s); also see FIGURE 74	Johnson, Matthey 4600. #1: "spectroscopically pure". #2: 0.35% In.	Single crystals. Cast in glass tubes; #1 was recrystallized before removing glass; lightly etched. #1: rod axis parallel to tetragonal crystal axis. #2: rod axis inclined 82° to tetragonal crystal axis. Measured in both the normal (in a longitudinal field of 0.04 T) and superconducting (s) states. Graph of ratio of the electronic component of the thermal conductivity of the superconducting state to the normal state as a function of the reduced temperature. Also measured the superconducting state of several specimens below 1 K.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-2; M-1, 2; N-3, 4; O-5; P-4, 5; Q-1; S-1, 5.	S.J. Laredo (1955).

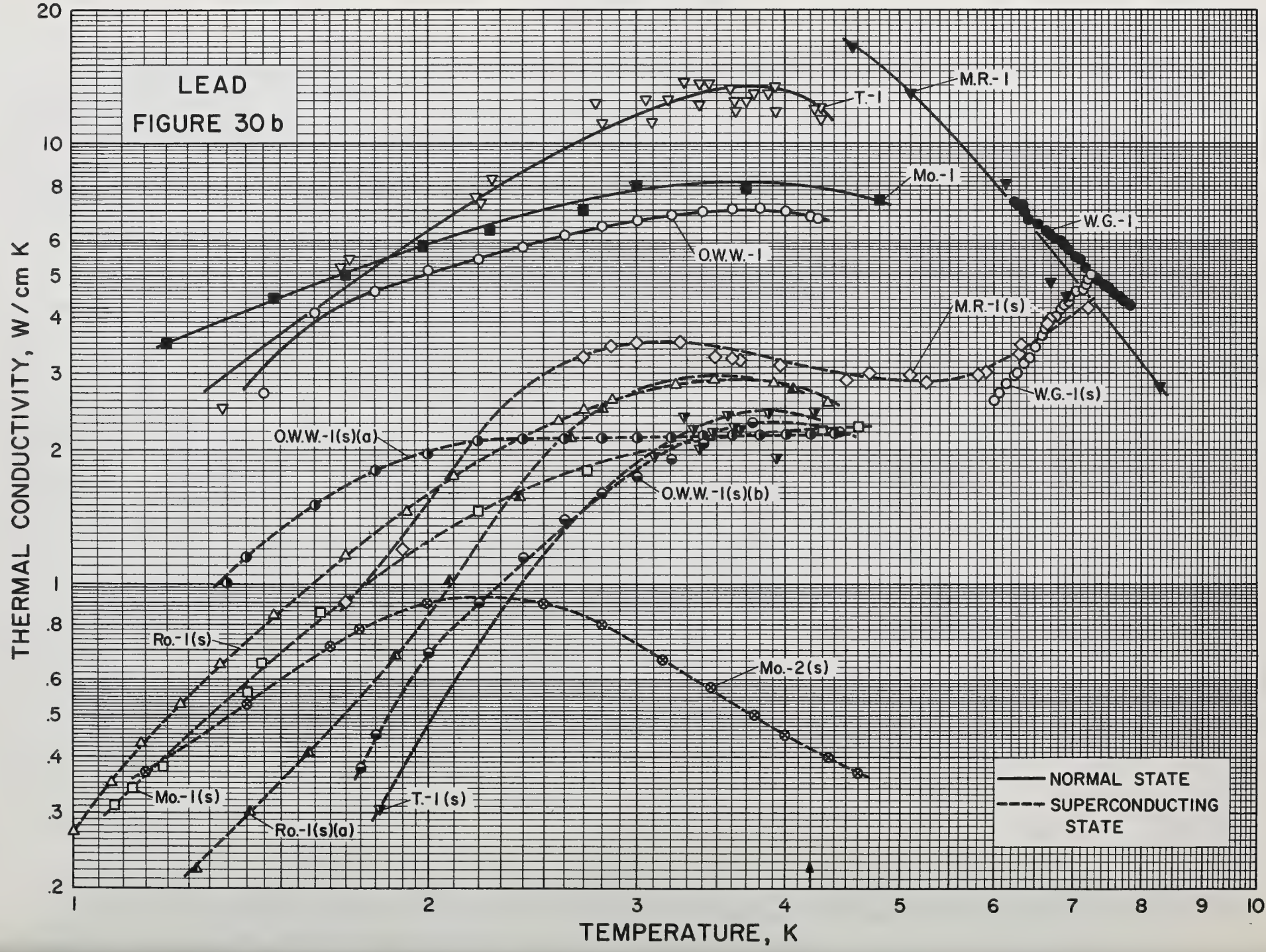
TIN (cont'd)
(See FIGURES 29a–29c)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	Measured the thermal conductivity in the normal and superconducting states between 1 and 5 K of tin doped with Bi, Hg, and Pb.	. . . . .	A. S. Boxer (1958).
G. L.	0.11% (atomic) Bi; RRR(27) = 162.	Measured in a field of 0.056 T.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-2; M-1, 2; S-1, 5.	M. Garfinkel and P. Lindenfeld (1958).
G.-1, 1(s), 2, 2(s), 3, 3(s)	#1: Vulcan Detinning Co.; "high purity"; RRR(20) = 80,000. #2: 5 part Johnson, Matthey Specpure and 8 parts Vulcan "high purity"; RRR(20) = 23,000. #3: equal parts of Johnson, Matthey Specpure and Hilger tin; RRR(20) = 4,500.	Single crystals. Prepared from extruded wire and seed crystal; crystallized the melt by slow cooling; etched, while seed attached, in HCℓ; seed removed. Rod axis parallel to [001] crystal axis. Measured in both the normal (in longitudinal fields) and superconducting (s) states. T_c = 3.695, 3.706, and 3.705 K, respectively. Graph of thermal resistivity as a function of magnetic field. Graph of the ratio of the thermal conductivity of superconducting to normal states as a function of reduced temperature. Seven other specimens also measured.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-2; L-1, 2; M-1; N-2, 3; O-7; P-2; S-1.	A. M. Guénault (1961).
Z.-1, 1(s), 2, 2(s); also see FIGURE 74	. . . . .	#1: rod axis parallel to [110] crystal axis. #2: rod axis parallel to [001] crystal axis. Measured in both the normal and superconducting (s) states. Also measured the superconducting state below 1 K. Graph and table of the ratio of the thermal conductivity of the superconducting and normal states as a function of the reduced temperature.	A-1; B-1; C-1; D-3(4); E-6; F-4; G-2; M-5; N-1, 3, 4; P-1; S-1, 5.	N. V. Zavaritskii (1961).
. . . . .	. . . . .	Effective perpendicular and parallel magnetic field effects on superconducting films.	. . . . .	D. E. Morris and M. Tinkham (1964).
. . . . .	. . . . .	Thermal resistivity in the normal, intermediate and superconducting states as a function of magnetic fields between 1.5 and 3.7 K.	. . . . .	A. J. Walton (1965).

TIN (cont'd)
(See FIGURES 29a–29c)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
P.-1, 1(s), 2, 2(s), 3, 3(s), 4, 4(s)	Johnson, Matthey. #1: 99.996 % pure; RRR = 6100. #2: Pb dopant, 0.52% (atomic); RRR = 2800. #3: Bi dopant, 0.78%; RRR = 17. #4: Hg dopant, 0.23%; RRR = 28.	Vacuum melted; extruded; polycrystalline wires; annealed for several days at ~ 200°C. #1: large grains 2 cm in length; T_c = 3.720 K. #2 - #4: grains ~ 0.1 mm in length; T_c = 3.752, 3.700, and 3.646 K, respectively. Measured in both the normal (in longitudinal fields) and superconducting (s) states. Measured other doped specimens also. Graphs of the ratios of the lattice component of the thermal conductivity and the superconducting state to the normal state as a function of reduced temperature. Also see TIN ALLOYS Table and Figures 48a and 48b.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-2; L-1, 2; M-1; N-3, 7; O-5; P-5; Q-1; S-1, 5.	G.J. Pearson, C.W. Ulbrich, J.E. Gueths, M.A. Mitchell, and C.A. Reynolds (1967); also G.J. Pearson (1963).
G.C. -1, 2, 3, 4, 5, 6, 7, 8	Spectroscopically pure Sn and Cd, with stock impurities < 1 x 10^{-3} %(atomic). Specimens are doped with the following amounts of Cd: #1-0.0046%(atomic); #2-0.0092; #3-0.0245; #4-0.0310; #5-0.0391; #6-0.0421; #7-0.0631; #8-0.122.	Single crystals; melted in vacuum; grown in glass tubing; annealed at 200°C for 72 hrs. Rod axes inclined 76, 79, 72, 81, 81, 59, 78, and 80°, respectively, from tetrad crystals. Also measured an undoped specimen that lies on H. -1 curve on FIG. 29b within experimental error; and measured two Cd doped specimens containing 0.251 and 0.321%(atomic) Cd which lie about 20% above and on curve P. -4 on FIG. 29c, respectively. Graph of ratio of superconducting to normal conductivity.	A-1; B-1; C-1; D-3(2); E-5; G-2; L-1, 2, 4; M-2; N-3, 7; P-1; Q-1.	J.E. Gueths, N.N. Clark, D. Markowitz, F.V. Burckbuchler, and C.A. Reynolds (1967).


LEAD
FIGURE 30a
NORMAL STATE
SUPERCONDUCTING STATE
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
H. Ra. - 1
W. - 1
Ra. - 1
W. - 2
W. - 1(s)
Ra. - 2(s)
H. Ra. - 1(s)
W. - 2(s)
Br. H. - 1
Br. H. - 1(s)
Ra. - 1(s)
M.O. - 1
M.O. - 1(s)


LEAD
FIGURE 30 b
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
M.R.-1
T.-1
Mo.-1
W.G.-1
O.W.W.-1
M.R.-1(s)
W.G.-1(s)
O.W.W.-1(s)(a)
O.W.W.-1(s)(b)
Ro.-1(s)
Mo.-2(s)
Mo.-1(s)
T.-1(s)
Ro.-1(s)(a)
NORMAL STATE
SUPERCONDUCTING STATE

LEAD
(See FIGURES 29a, 30a, 30b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	"Pure".	k = 0.35 at 0°C.	A-5; B-1; C-1; D-7(9); F-5; G-3; S-1, 3, 5.	L. Lorenz (1881).
. . . . .	Kahlbaum; "pure"; traces of Bi, Cu, Fe, and Ni (total not over 0.05%).	Cast. k = 0.35 at 18°C. Specific density of 11.32.	A-4; B-1; C-2, 3; D-1(3); E-1; F-4; G-3; S-1, 2, 3, 5.	W. Jaeger and H. Diesselhorst (1900).
. . . . .	. . . . .	k = 0.35 at 25°C; k = 0.45 at 90K.	. . . . .	P. Macchia (1907).
L.-Pb	Baxendale; "pure".	Lathe-turned from a bar. Specific density of 11.29 at 25°C.	A-1; B-1; C-1; D-2(2); E-2; F-4; G-3; L-1; S-1, 5.	C.H. Lees (1908).
Me.-Pb	Kahlbaum; 0.002% impurities; RRR = 29.	Cold-drawn.	A-4; B-1; C-3; D-2(2); E-5; F-4; G-2; L-1; M-1; P-1; S-1, 2, 4, 5.	W. Meissner (1915).
. . . . .	Kahlbaum; "pure".	Results are 3% lower than Me.-Pb at low temperatures and 5% greater at high temperatures.	A-1; B-1; C-1; D-1(2); E-1; F-5; G-3; L-1; M-1; S-1,5.	R. Schott (1916).
. . . . .	. . . . .	k = 0.38 at 12°C; k = 0.36 at 23°C.	A-1; B-3; C-2; D-1(2); F-5; G-3; L-1; M-1.	T. Peczalski (1917).
. . . . .	Kahlbaum.	k = 0.37 at 0°C; k = 0.38 at 26.5 °C.	A-4; B-3; C-3; D-1(3); E-8; F-4; G-3; L-1; M-1; S-1.	M.D. O'Day (1924).
B.L.-Pb	National Bureau of Standards; "very high purity".	. . . . .	A-5; B-1; C-1; D-1(6); E-8; F-5; G-3; L-1; M-1.	C.C. Bidwell and E.J. Lewis (1929); also C.C. Bidwell (1940).
. . . . .	. . . . .	Measured the relative change in thermal conductivity at low temperatures; absolute values not given.	. . . . .	W.J. de Haas and H. Bremmer (1931).
Br.H.-1, 1(s)-Pb	. . . . .	Measured in both the normal (in fields up to 0.1 T) and superconducting (s) states.	A-1; B-1; C-1; D-2, 4, 5(2); E-2; F-4; G-3; L-1, 2; M-1; N-2, 3; S-1, 5.	H. Bremmer and W.J. de Haas (1936).

LEAD (cont'd)

(See FIGURES 29a, 30a, 30b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	Measured changes in thermal conductivity during superconducting transition in transverse fields up to 0.09 T.	. . . . .	K. Mendelssohn and R.B. Pontius (1937).
H.Ra.-1, 1(s)-Pb	Hilger; "pure".	Melted in high vacuum in a glass tube at low pressures; pressed under nitrogen; cooled and glass dissolved in HF. Single crystal. Measured in the normal (in transverse magnetic fields up to 0.08 T), intermediate, and superconducting (s) states. T_c = 7.13 K. Graph of thermal resistance as a function of magnetic field.	A-1; B-1; C-1; D-4(2); E-5; F-4; G-3; L-1; M-1; N-2, 3.	W.J. de Haas and A. Rademakers (1940).
Ra.-1, 1(s), 2(s)	Hilger HS.	Single crystals. Measured in both the normal (in a longitudinal magnetic field of 0.085 T) and superconducting (s) states.	A-1; B-1; C-1; D-2(2); E-2, 5; F-4; G-2; M-1; N-3; P-5.	A. Rademakers (1949).
M.O.-1, 1(s)-Pb	Johnson, Matthey 1932; ~ 0.02% Bi.	Measured in the normal (in longitudinal and transverse magnetic fields up to 0.1 T), intermediate, and superconducting (s) states. Another pure specimen was also measured. Graph of thermal conductivity as a function of magnetic field.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-3; L-1; M-1, 2; N-2, 3.	K. Mendelssohn and J.L. Olsen (1950c).
. . . . .	. . . . .	Studied the thermal conductivity in the normal, intermediate, and superconducting states in a transverse magnetic field up to 0.08 T.	. . . . .	R.T. Webber and D.A. Spohr (1951).
M.R.-1, 1(s)-Pb	Goodlass Wall and Lead Industries; 99.998% pure Tadanac lead.	Single crystal. Measured in both the normal and superconducting (s) states.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-1; N-2, 3.	K. Mendelssohn and H.M. Rosenberg (1952b).
See FIGURE 74	Same material as above.	Single crystal. Values in the superconducting state: k = 0.12 at 1 K; k = 1.32 at 1.1 K; k = 1.32 at 1.1 K; k = 1.88 at 1.15 K. Also measured the normal, intermediate, and superconducting states at 0.43, 0.59, and 1.5 K as a function of magnetic field. Also measured the superconducting state below 1 K.	A-1; B-1; C-1; D-3(2); F-4; G-2; N-2, 3.	J.L. Olsen and C.A. Renton (1952).

LEAD (cont'd)
(See FIGURES 29a, 30a, 30b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	Measured in transverse and longitudinal magnetic fields up to 0.4 T from 2.7 to 6.4 K.	. . . . .	K. Mendelssohn and H.M. Rosenberg (1953).
T.-1, 1(s)	Johnson, Matthey; 99.999% pure.	Cold-worked. Measured in both the normal (in fields up to 0.09T) and superconducting (s) states. Two other specimens from same lot were measured in the superconducting states with results similar to #1(s). Graph of ratio of the thermal conductivity of the superconducting and normal states as a function of reduced temperature.	A-1; B-5; C-1; D-3, 6(2); E-6; F-4; G-3; L-1, 2; M-1; N-2, 3, 8.	T.P. Tseng (1954).
. . . . .	. . . . .	Review of M.R. above.	N-8.	H.M. Rosenberg (1955).
Mo.-1, 1(s), 2(s)	#1: Johnson, Matthey 560; 99.99% pure. #2(s): 0.7% (atomic) Bi.	Single crystals. #1: cast in brass molds in vacuum. Annealed in vacuum for several days just below the melting point. #2: cast in pyrex in vacuum. The normal state varies linearly from k = 0.042 at 1.3 K to k = 0.19 at k = 4.7 K. The superconducting (s) state is shown. Measured in both the normal (in transverse magnetic fields up to 0.6 T) and superconducting (s) states. Also measured one other pure specimen, three specimens with Bi < 0.1% and two specimens with either Sn or Tℓ impurities of < 0.1%.	A-1; B-1; C-1; D-3(2); E-5, 6; F-4; G-2; L-1, 2; M-1, 2; N-2, 3; O-5; P-3-5, 8, 9; Q-1, 3; S-1, 5.	H. Montgomery (1958).
. . . . .	. . . . .	Preliminary work; reported by P.M. Rowell (1960).	. . . . .	K. Mendelssohn (1958).

LEAD (cont'd)

(See FIGURES 29a, 30b, 30b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
Ro.-1(s), 1(s)(a)	Johnson, Matthey; 99.99%.	Melted; solidified slowly from one end. Annealed for three days at 270°C. Single crystal. Measured in the superconducting (s) state. The specimen was then bent at 4 K, equivalent to a longitudinal strain, and remeasured (a). Specimen also annealed at room temperature and remeasured, with intermediate results between 1(s) and 1(s)(a). Also measured a Pb-specimen with 1% Bi in the same manner.	A-1; B-1; C-1; D-3(2); E-5,6; F-4; G-2; N-3; P-2, 3, 5, 9; Q-1.	P. M. Rowell (1960).
W.-1, 1(s), 2, 2(s)	Oak Ridge National Laboratories; "pure"; enriched in various Pb isotopes. #1 < 0.1% metallic impurities; 206.11 a.m.u. #2: < 0.5% metallic impurities; 206.19 a.m.u.	Cast from melt in C-coated glass molds; annealed in vacuum for 5 hrs. at 260°C. Nearly single crystals. Measured in both the normal (in a field of 0.12 T) and superconducting (s) states. Three other specimens also measured. Graph of the ratio of the thermal conductivity of the superconducting and normal states as a function of the reduced temperature. Graph of the thermal resistivity as a function of magnetic fields.	A-1; B-1; C-1; D-3(2); E-5; F-5; G-3; L-1; M-1, 2; N-2, 3; P-2, 8.	C. L. Wolff (1961).
W. G.-1, 1(s)	Consolidated Mining and Smelting; 99.9999% pure.	Single crystal. Measured in both the normal (in longitudinal magnetic fields up to 0.085 T) and superconducting (s) states. T_c = 7.226 K. Graph of the ratio of the thermal conductivity of the superconducting and normal states as a function of the reduced temperature.	A-1; B-1; C-1; D-3(2); E-5; F-5; G-3; L-1; M-1; N-3.	J. H. P. Watson and G. M. Graham (1963).
. . . . .	. . . . .	Magnetic field effects on superconducting films.	. . . . .	D. E. Morris and M. Tinkham (1964).

LEAD (cont'd)

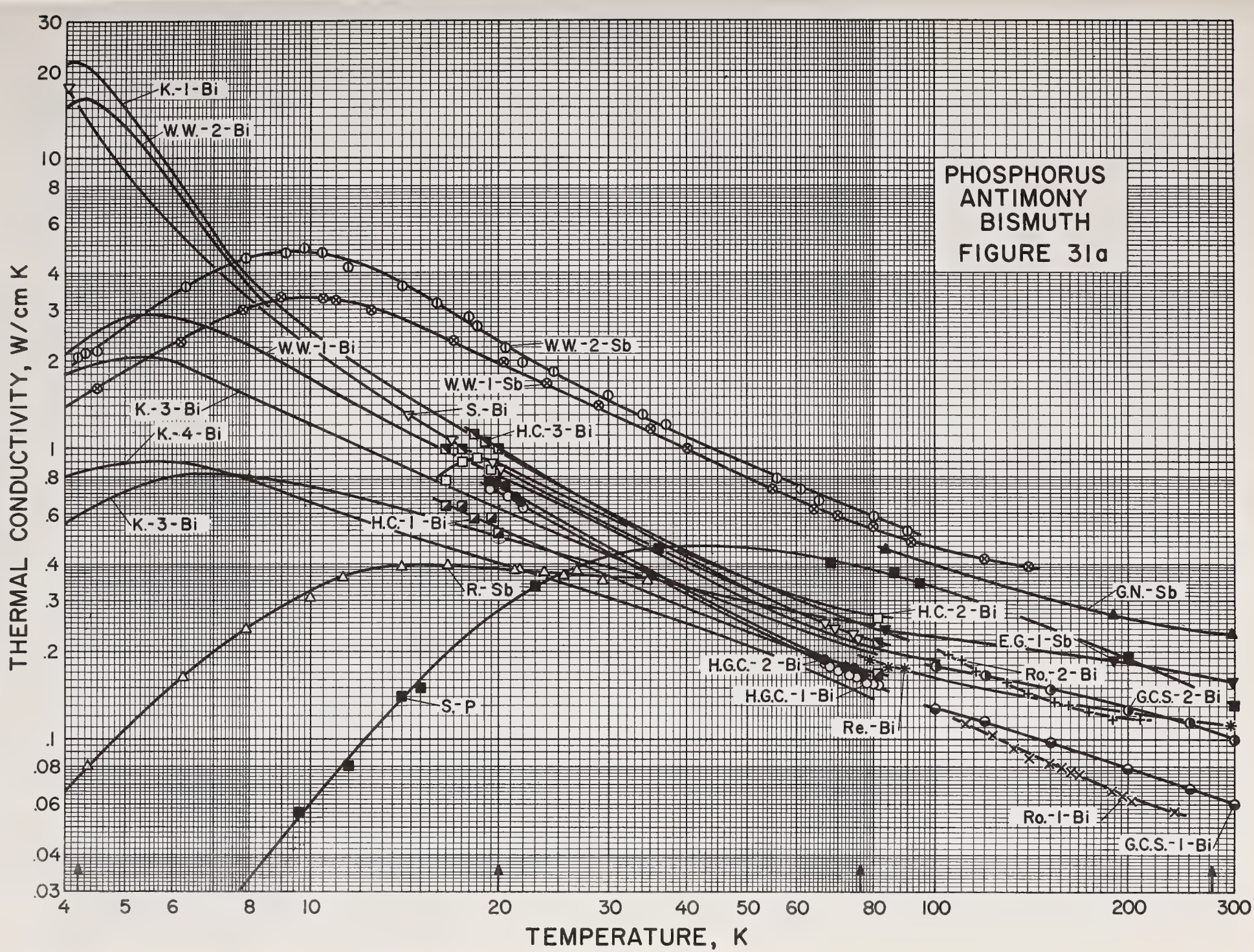
(See FIGURES 29a, 30a, 30b)

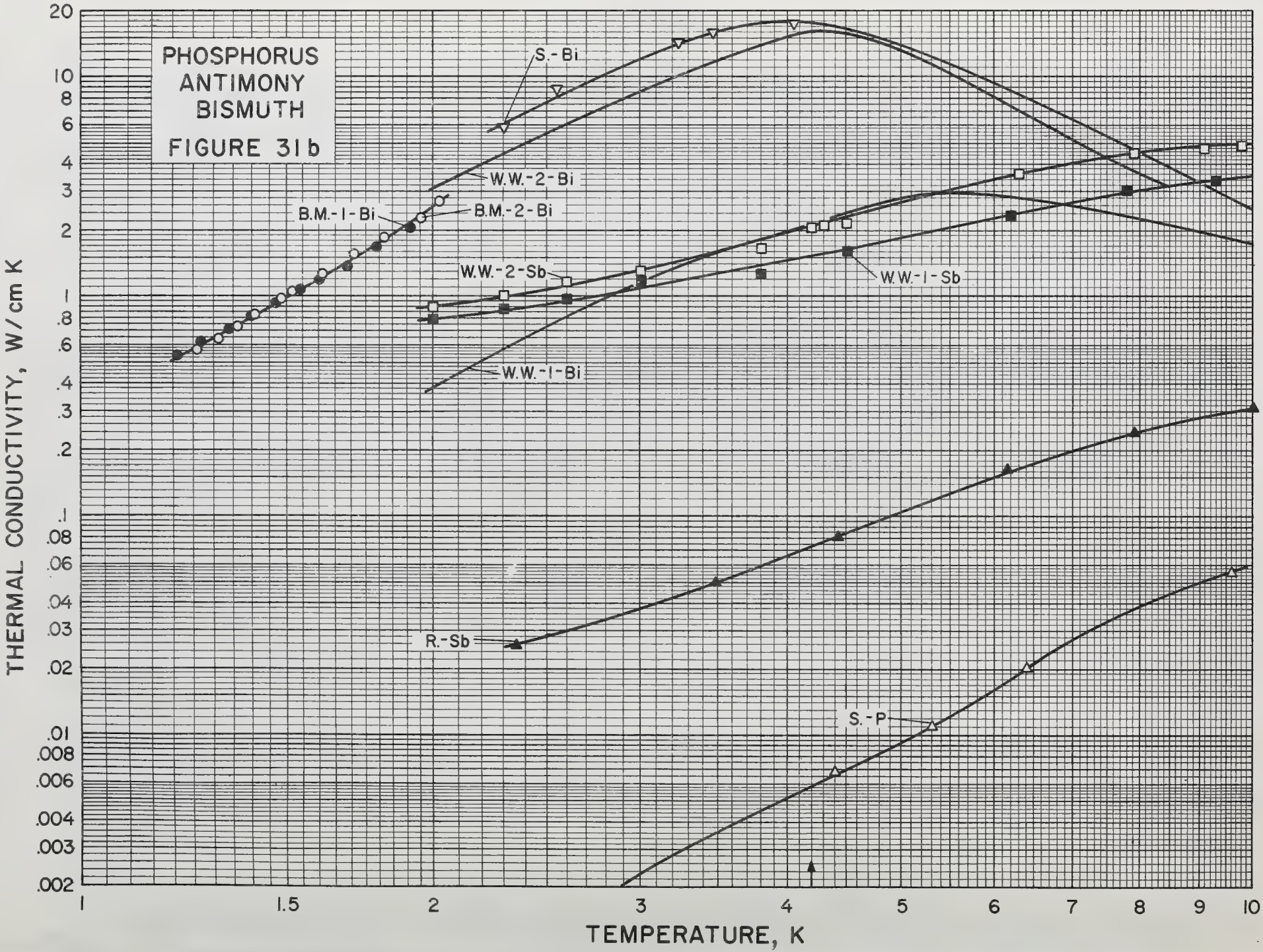
CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
O.W.W.-1, 1(s)(a), 1(s)(b)	Semi Elements; < 5 ppm metallic impurity.	#1: as supplied; single crystal; diameter of 13.04 mm. #1(s)(a): superconducting state of specimen #1 after being slightly strained by electrolytic etching and the surface being smoothed by electropolishing. #1(s)(b):diameter reduced to 1.35 mm by etching and smoothing again, and remeasured in the superconducting (s) state. Other specimens, with diameters between those of #1 and #1(b), had intermediate thermal conductivity values in the superconducting state. All specimens had identical normal state values. Measured in both the normal (in magnetic fields up to 0.09 T), intermediate, and superconducting (s) states.	N-2, 3; O-5; P-4.	J. L. Olsen, A. Waldvogel, and P. Wyder (1966).
. . . . .	Department of Mines and Technical Surveys (Canada); 99.999% pure.	k = 0.362 at -50°C; k = 0.355 at 0°C.	A-1; B-1; C-1; D-1(2); F-4; G-2; L-1; S-1, 5.	T. M. Dauphinee, L. D. Armstrong, and S. B. Woods (1966).

NITROGEN

(See FIGURE 1)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
R.-N_2	. . . . .	"The structure of sublimed samples was not known, but is suspected to be highly polycrystalline, perhaps even tendrilous." Other measurements showed the samples to contain 10-30% voids. The dashes merely connect the widely separated points; there may be a maximum between 4 and 20K.	A-7; B-4; C-1; D-3(2); E-5; F-4; G-3; P-7.	H. M. Roder (1962).


PHOSPHORUS
ANTIMONY
BISMUTH
FIGURE 31a
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
K.-1-Bi
W.W.-2-Bi
W.W.-1-Bi
W.W.-2-Sb
W.W.-1-Sb
S.-Bi
H.C.-3-Bi
K.-3-Bi
K.-4-Bi
K.-3-Bi
H.C.-1-Bi
R.-Sb
S.-P
G.N.-Sb
H.C.-2-Bi
E.G.-1-Sb
H.G.C.-2-Bi
Ro.-2-Bi
H.G.C.-1-Bi
G.C.S.-2-Bi
Re.-Bi
Ro.-1-Bi
G.C.S.-1-Bi
30
20
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
4
5
6
8
10
20
30
40
50
60
80
100
200
300


PHOSPHORUS
ANTIMONY
BISMUTH
FIGURE 31b
S.-Bi
W.W.-2-Bi
B.M.-1-Bi
B.M.-2-Bi
W.W.-2-Sb
W.W.-1-Sb
W.W.-1-Bi
R.-Sb
S.-P
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
20
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
.01
.008
.006
.004
.003
.002
1
1.5
2
3
4
5
6
7
8
9
10

PHOSPHORUS
(See FIGURES 31a and 31b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	Yellow phosphorus; water free.	k = 0.0042 at 16°C; k = 0.00425 at 20°C; k = 0.0047 at 25°C.	A-3; B-3; C-1; D-2(1); F-5; G-3.	H. Krämer and K. Schmeiser (1962).
. . . . .	"Chemically pure"; white phosphorus; 0.36% dissolved H_2O; < 0.01% total impurities; body-center-cubic (white; α-phase).	Yellow phosphorus treated with warm chromic acid and distilled water until water-white. k = 0.0023 at 26°C.	A-3; B-3; C-1; D-2(1); F-5; G-3; O-3; P-7.	A. G. Turnbull (1964).
S.-P	Fisher Scientific; 99.8% pure, starting material; orthorhombic (black); carrier concentration of $10^{15}/cm^3$.	Prepared from liquid P by cooling the melt from 1200°C under a pressure of 2.3×10^4 atm; crystallite size of $\sim$ 200μ; some preferred orientation of the anisotropic crystallites. p-type. Rod axis approximately in the a-b crystal planes. Resistivity at 300 K of 3.1 Ω-cm.	A-1; B-1; C-1; D-1(2); E-1, 4; F-4; G-2; O-3, 5; P-4, 7; S-1.	G. A. Slack (1965).

ARSENIC

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	Distilled in vacuum at ~ 400°C; condensed on glass; deposits ground and smoothed. k = 0.368 at 20°C. Measured in magnetic fields of 0.4 and 0.8 T.	A-4; B-4; C-3; D-1(2); E-8; F-5; G-3; N-2; S-1,2,5.	N. C. Little (1926).

ANTIMONY

(See FIGURES 31a and 31b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	k = 0.18 at 0°C.	A-5; B-1; C-1; D-7(9); F-5; G-3; S-1, 3, 5.	L. Lorenz (1881 a).
E.G.-Sb	Kahlbaum	Melted under H_2 atmosphere; cast; slowly cooled	A-1; B-1; C-1; D-1(2); F-4; G-3; L-1; M-2; S-1, 2, 5.	A. Eucken and G. Gehlhoff (1912).
G.N.-Sb	Kahlbaum; "pure".	Melted under H_2 atmosphere; cast; slowly cooled	A-1; B-2; C-1; D-1(4); E-1; F-4; G-3; L-1; M-1, 2; S-1, 2, 5.	G. Gehlhoff and F. Neumeier (1913 a).
. . . . .	Same as above.	Measured compressed powder at 5000 kg/cm^2. Measured at the same temperature as G.N.-Sb; results approximately 45% lower.	. . . . .	G. Gehlhoff and F. Neumeier (1913 b).
. . . . .	Kahlbaum; "chemically pure".	Measured effect of grain size on thermal conductivity; specimen with largest grains had a conductivity close to G.N.-Sb curve.	. . . . .	A. Eucken and O. Neumann (1924).
. . . . .	Kahlbaum; "pure".	Measured effect of transverse magnetic fields up to 1.2 T on the thermal conductivity for single and polycrystalline rods; at 80 and 90 K results agree with G.N.-Sb curve.	. . . . .	K. Rausch (1947).
R.-Sb	Johnson, Matthey; RRR(20) = 6.37.	Extruded wire. Annealed in vacuum for 2 hrs at 500°C. Graphs of lattice and electronic thermal conductivity as a function of temperature.	A-1; B-5; C-1; D-4(2); E-4; F-4; G-2; L-1; M-1; P-2, 3; S-1.	H.M. Rosenberg (1955).
W.W.-1, 2-Sb	Bradley Mining. #1:"extra high purity"; RRR(22)= 840. #2:"high purity"; RRR(22)= 770.	#1: unannealed. #2: zone refined; annealed for a week at about 600°C. Crystal grains of #2 varied from about 2 to 5 mm in width. Measured in magnetic fields up to 0.1 T. Graph of lattice and electronic thermal conductivity as a function of temperature.	A-1; B-1; C-1; D-4(2); E-1,5; F-4; G-1; L-1, 2; N-3, 5, 7; O-3; P-3, 8; Q-1; S-1, 5.	G.K. White and S.B. Woods (1958 b).

ANTIMONY (cont'd)

(See FIGURES 31a and 31b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	Measured the effects of magnetic fields up to 1.8 T at temperatures between 1.6 and 4.0 K on the lattice thermal conductivity.	. . . . .	J.R. Long, C.G. Grenier, and J. M. Reynolds (1965).
. . . . .	. . . . .	Measured the lattice component of the thermal conductivity.	. . . . .	R.S. Blewer and N.H. Zebouni (1966).

BISMUTH
(See FIGURES 31a and 31b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	k = 0.071 at 0°C.	A-5; B-1; C-1; D-7(9); F-5; G-3; S-1, 3, 5.	L. Lorenz (1881 a).
. . . . .	Kahlbaum; "pure"; traces of Fe and Pb (< 0.03%).	Cast. k = 0.081 at 18°C. Specific density of 9.78 at 18°C.	A-4; B-1; C-2, 3; D-1(3); E-1; F-4; G-3; S-1, 2, 3, 5.	W. Jaeger and H. Diesselhorst (1900).
. . . . .	. . . . .	k = 0.234 at 87 K; k = 0.105 at 194 K; k = 0.080 at 291 K.	A-1; B-1; C-2; D-1(2); F-5; G-3; S-1, 5.	E. Giebe (1903).
. . . . .	Kahlbaum; "pure".	Melted in H_2 atmosphere; cooled slowly. k = 0.26 at 83 K; k = 0.108 at 194 K; k = 0.102 at 273 K.	A-1; B-2; C-1; D-1(4); E-1; F-4; G-3; L-1; M-1, 2; S-1, 2, 5.	G. Gehlhoff and F. Neumeier (1913 a).
. . . . .	Same as above.	Measured compressed powder at 5000 kg/cm^2. Measured at the same temperatures as the above paper; results are approximately 20% lower for the thermal conductivity.	. . . . .	G. Gehlhoff and F. Neumeier (1913 b).
. . . . .	0.02% Pb; trace of Fe.	Single crystals; annealed for some days. #1: rod axis parallel to trigonal axis; k = 0.065. #2: rod axis perpendicular to trigonal axis; k = 0.093. Both at 17°C.	A-7; B-2; C-1, 2; D-1(2); F-3; G-3; N-4.	G. W. C. Kaye and J. K. Roberts (1923).
. . . . .	. . . . .	Measured effect the apparent effect of grain size.	. . . . .	A. Eucken and O. Neumann (1924).
. . . . .	. . . . .	Measured effect of transverse magnetic fields up to 1.1 T on the thermal conductivity of single crystals at 27°C.	. . . . .	G. W. C. Kaye and W. F. Higgins (1929 b).
Re.-Bi	Merck; "pure".	Single crystal; pulled from the melt; rod axis inclined 80° to crystal axis. Also studied effect of transverse magnetic fields up to 0.59 T. Table of electronic and lattice components.	A-1; B-1; C-1; D-1(2); E-1,5; F-4; G-3; L-1; M-1; N-2; P-1; S-1, 5.	R. Reddemann (1934).

BISMUTH (cont'd)

(See FIGURES 31a and 31b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
Ro.-1, 2-Bi	. . . . .	Single crystals. #1: rod axis parallel to crystal trigonal axis. #2: rod axis perpendicular to crystal trigonal axis. Both measured in a transverse magnetic field of 0.78 T.	A-1; B-1; C-1; D-1(2); F-4; G-3; L-1; S-1.	M. T. Rodine (1934).
H. C.-1, 2, 3-Bi	Hilger 8016; 99.995% pure; trace of Ag.	Single crystals. #1: rod axis parallel to trigonal crystal axis. #2: rod axis parallel to binary axis. #3: rod axis parallel to bissectrix of binary axes.	A-1; B-1; C-1; D-4(2); E-5; F-4; G-3; L-1; M-1; N-4.	W. J. de Haas and W. H. Capel (1934a, b).
. . . . .	. . . . .	Measured effect of transverse magnetic fields up to 0.61 T on the thermal conductivity at 78 and 90 K.	. . . . .	E. Grüneisen and J. Gielessen (1936, 1937).
H. G. C.-1, 2-Bi	#1: Hilger 9506; 0.002% Ag; < 0.001% Pb; minute trace of Cu; RRR = 22. #2: Hilger 10283; 0.001% Ag; minute trace (< 4 ppm) Pb; RRR = 31.	Single crystals; grown by the Schubnikow method. #2: recrystallized 5 times. Rod axes parallel to trigonal crystal axes. Measured effect of transverse magnetic fields up to 0.51 T. Graph of thermal resistivity as a function of transverse magnetic field. Table of electronic and lattice components.	A-1; B-3; C-1; D-2(2); E-2; F-4; G-2; L-1; M-1; N-4; S-1, 5.	W. J. de Haas, A. N. Gerritsen, and W. H. Capel (1936).
. . . . .	. . . . .	Single crystal. k = 0.054 at 25°C for rod axis parallel to trigonal axis; k = 0.093 at 25°C for rod axis perpendicular to the trigonal axis. Measurements made in transverse and longitudinal magnetic fields up to 2.3 T.	. . . . .	G. W. C. Kaye (1939).
S.-Bi	Hilger.	Recrystallized 3 times. Rod axis inclined 82° to the crystal axis. Measured in magnetic fields up to 0.42 T.	B-1; D-5(2); L-1; M-1; N-2; P-5; S-1.	S. Shalyt (1944).
. . . . .	Merck.	k = 0.053 at 14°C for a single crystal, rod axis parallel to trigonal axis; k = 0.094 at 14°C for a single crystal, rod axis perpendicular to trigonal axis. Several polycrystals were also measured.	A-7; B-2; C-1, 2; D-3(4); F-3; G-3; N-4.	S. Nishioka (1949).

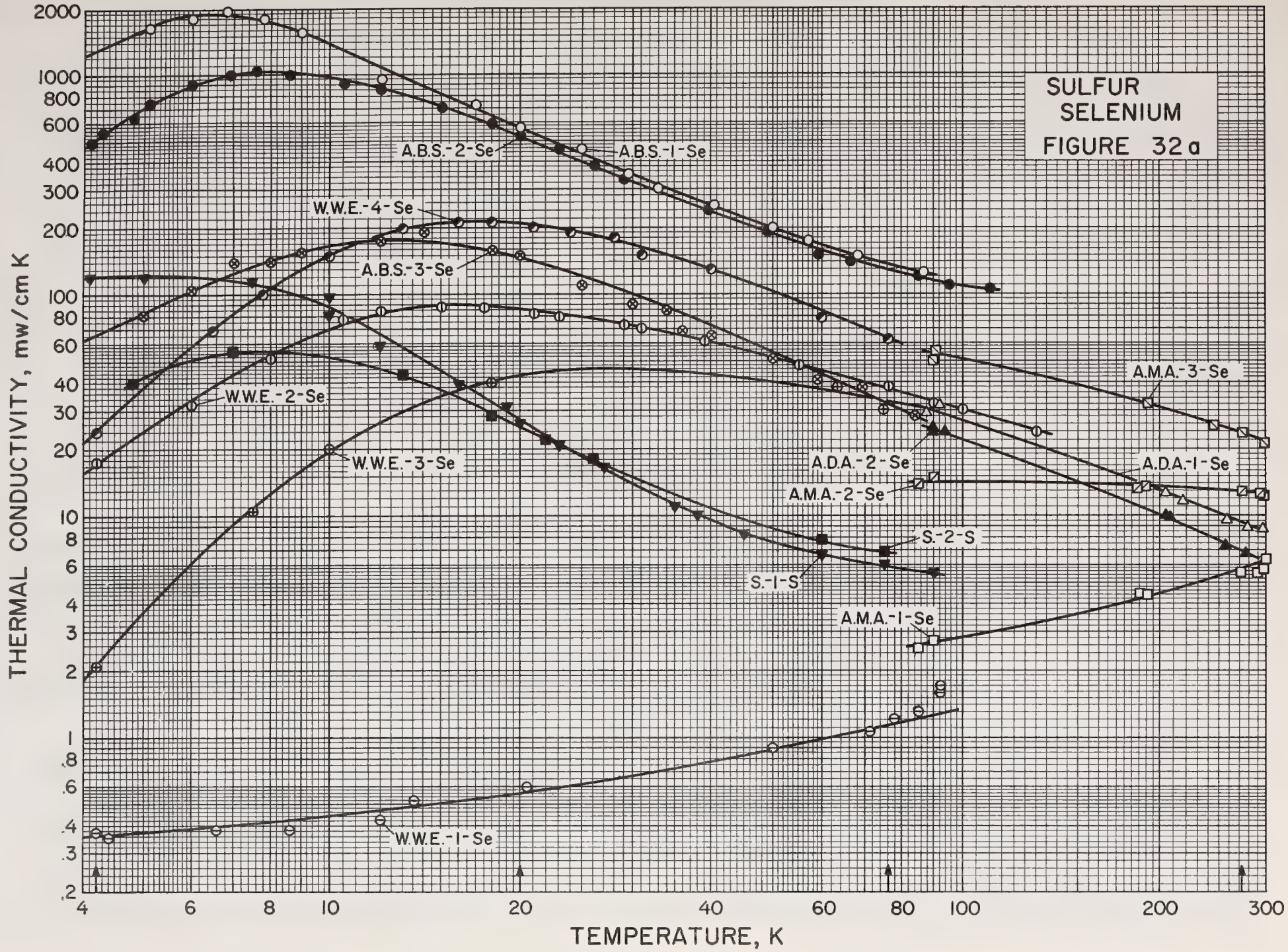
BISMUTH (cont'd)
(See FIGURES 31a and 31b)

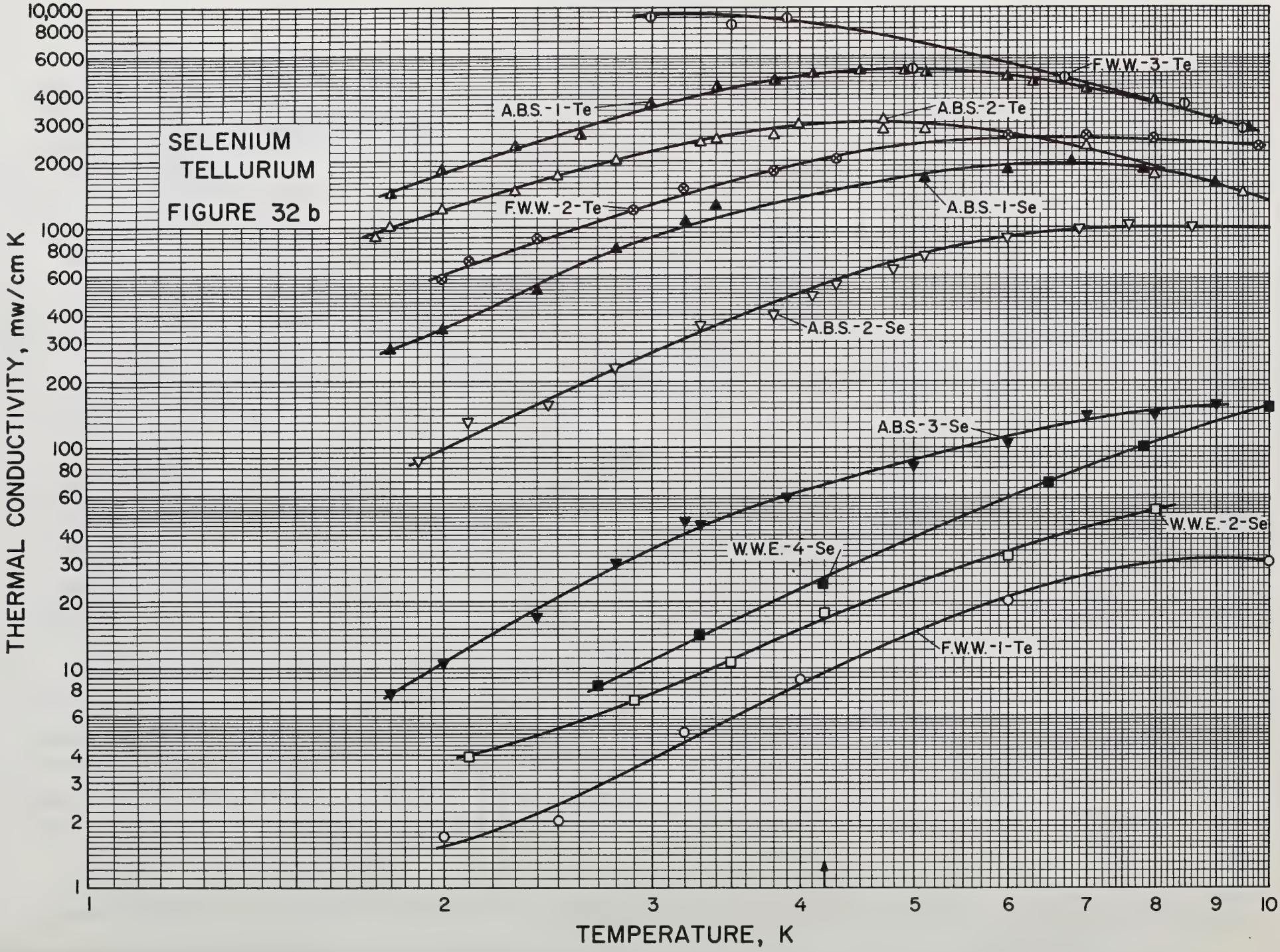
CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	Measured effect of transverse magnetic fields up to 1.02 T on the thermal conductivity at 130, 153, 178, and 268 K.	. . . . .	E. Grüneisen, K. Rausch, and K. Weiss (1950).
. . . . .	. . . . .	k = 0.078 at 25°C. Measured the effect of transverse magnetic fields up to 11 T at 25°C.	. . . . .	K.I. Amirkhanov, A.Z. Daibov, and V.P. Zhuze (1954).
. . . . .	. . . . .	Measured thermal conductivity of a single crystal in transverse magnetic fields up to 1.3 T at 1.6 K.	. . . . .	M.C. Steele and J. Babiskin (1955).
. . . . .	. . . . .	Unpublished report on values at 20°C and greater.	. . . . .	R.B. Sawyer (1955).
W.W.-1,2-Bi	#1: Mining and Chemical Products; 99.97% original purity; RRR(22) = 1.3. #2: Varlacoid Chemical; RRR(22) = 49.	#1: cast and cooled quickly in a glass tube. Columnar crystals penetrated to the center; 16-18 crystals exposed on circular section. #2: cut from a zone-refined bar; consisted of crystals 1-2 cm long, 2-4 mm wide, slightly inclined to the rod axis. Also measured in magnetic fields up to 1.4 T. Three other specimens had intermediate thermal conductivity values. Graph of electronic thermal conductivity.	A-1; B-1; C-1; D-4(2); E-1,5; F-4; G-1; L-1,2; O-3,5; P-4,5; S-1,5.	G.K. White and S.B. Woods (1958b, 1955).
. . . . .	. . . . .	Measured thermal conductivity of a single crystal in magnetic fields up to 1.6 T. Zero field values are within 2% of R. Gillingham (1962) and H.J. Mackey (1963) between 2 and 3.5 K; at 4.1 K, values fall 15% lower.	. . . . .	C.G. Grenier, J.M. Reynolds, and J.R. Sybert (1963).

BISMUTH (cont'd)

(See FIGURES 31a and 31b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
G.C.S.-1,2-Bi	American Smelting and Refining 99.999% pure (stock).	Single crystals grown in graphite mold in vacuum by a modified Bridgman technique; cut by a jeweler's saw, ends lapped flat and parallel; etched in nitric acid. #1: rod axis parallel to trigonal axis. #2: rod axis perpendicular to trigonal axis. Graph of lattice thermal resistivity and electronic thermal conductivity as a function of temperature.	A-1; B-1; C-1; D-1(2); F-4; G-2; L-1,2,9; M-1; N-4,5; O-3,5; R-1; S-1,2,5.	C.F. Gallo, B.S. Chandrasekhar, and P.H. Sutter (1963).
B.M.-1,2-Bi	99.9999% pure. #1: RRR(27) = 140. #2: RRR(27) = 104.	Single crystals. #1: rod axis parallel to the bisectrix axis. #2: rod axis parallel to the trigonal axis. Specimens measured in a field of about 0.05 T. Also measured effect of transverse magnetic fields up to 0.2 T on the thermal conductivity. Observed de Haas-van Alphen oscillations.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-3; L-1; M-1; O-5,6; P-5; Q-1; S-1.	S.M. Bhagat and D. D. Manchon, Jr. (1967a,b).
K.-1,2,3,4-Bi	#1: pure. #2: 0.1 (atomic) Te. #3: 0.1 Sn. #4: 0.1 Sn.	Single crystals; specimen size of 2.5-2.7 mm diameter and 50-60 mm length. #1-#3: rod axis parallel to C_1 axis. #4: rod axis parallel to C_3 axis.	A-1; B-1; C-1; D-4(2); E-5; F-4; G-3; O-2,3,6; P-2,5,12.	M.E. Kuznetsov, V.S. Oskotskii, V.I. Pol'shin, and S.S. Shalyt (1970).


SULFUR
SELENIUM
FIGURE 32a
THERMAL CONDUCTIVITY, mw/cm K
TEMPERATURE, K
A.B.S.-2-Se
A.B.S.-1-Se
W.W.E.-4-Se
A.B.S.-3-Se
W.W.E.-2-Se
W.W.E.-3-Se
A.M.A.-3-Se
A.D.A.-2-Se
A.D.A.-1-Se
A.M.A.-2-Se
S.-2-S
S.-1-S
A.M.A.-1-Se
W.W.E.-1-Se
2000
1000
800
600
400
300
200
100
80
60
40
30
20
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
4
6
8
10
20
40
60
80
100
200
300


SELENIUM
TELLURIUM
FIGURE 32 b
THERMAL CONDUCTIVITY, mw/cm K
TEMPERATURE, K
10,000
8000
6000
4000
3000
2000
1000
800
600
400
300
200
100
80
60
40
30
20
10
8
6
4
3
2
1
1
2
3
4
5
6
7
8
9
10
F.W.W.-3-Te
A.B.S.-1-Te
A.B.S.-2-Te
F.W.W.-2-Te
A.B.S.-1-Se
A.B.S.-2-Se
A.B.S.-3-Se
W.W.E.-2-Se
W.W.E.-4-Se
F.W.W.-1-Te

SULFUR
(See FIGURE 32a)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	#1: rhombic crystalline sulfur: k = 2.9 mW/cm-K at 0°C; k = 6.4 mW/cm-K at 83 K. #2: amorphous sulfur, made by casting boiling sulfur: k = 2.0 mW/cm-K at 0°C; k = 1.6 mW/cm-K at 83 K.	A-1; B-4; C-1; D-1(2); F-4; G-3.	A. Eucken (1911 a).
. . . . .	. . . . .	k = 2.6 mW/cm-K at 277 K.	A-1; B-4; C-1, 2; D-1(2); F-5; G-3.	C. Niven and A. E. M. Geddes (1912).
. . . . .	. . . . .	Rhombic aggregate; k = 2.7 mW/cm-K at 20°C.	A-7; B-4; C-1; D-1(2); F-5; G-3.	G. W. C. Kaye and W. F. Higgins (1929 a).
. . . . .	. . . . .	Rhombic crystal; cast, cooled slowly; random distribution of crystals; two specimens, values within 1% of each other; k = 2.62 mW/cm-K at 278 K; k = 2.57 mW/cm-K at 20°C.	A-7; B-3; C-1, 2; D-1(2); F-5; G-3.	S. E. Green (1952).
. . . . .	. . . . .	α-sulfur (rhombic); k = 0.99 mW/cm-K at 12°C.	A-6; B-4; C-'.	Y. Yoshizawa, A. Sugawara, and E. Yamada (1964).
S.-1, 2-S	> 99% starting purity.	Single crystals; orthorhombic; slowly grown from a CS_2 solution at room temperature for about a week; transparent, but yellowish; a few growth flaws visible. #1: rod axis parallel to c-axis. #2: rod axis in the a b plane, perpendicular to the c-axis.	A-1; B-1; C-1; D-1(2); E-1,4; G-2; O-3, 6; P-7.	G. A. Slack (1965).

SELENIUM

(See FIGURES 32a and 32b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	Vitreous disc; prepared by pouring molten selenium into a hot iron mold. Average value: k = 1.4 mW/cm-K at 24°C. Crystalline disc; prepared by heating in an oil oven ranging from 160 to 214 °C, gradually cooled, ground and polished. Average value: k = 6.3 mW/cm-K at 27°C. After 1 year, thermal conductivity decreased to 4.1 mW/cm-K. Also measured thermal conductivity of vitreous discs aged for different lengths of time.	A-1; B-4; C-1; D-1(2); F-4; G-3; S-1.	E. D. Sayce (1917).
. . . . .	99.996% starting purity.	Crystalline, containing Br impurities; vitreous Se containing Br was fused, then poured into beakers, kept in an oven at 130°C for 30 min., then at 200°C for 25 min.; polished. Hexagonal crystalline Se, measured at 20°C, with various concentrations of Br: pure, k = 29.2 mW/cm-K; 0.065% (weight), k = 14 mW/cm-K; 0.5% Br, k = 24.8 mW/cm-K. Amorphous Se, at 27.5°C, containing various concentrations of Br: pure, k = 12.9 mW/cm-K; 0.065%, k = 5.7 mW/cm-K; 0.5%, k = 10.1 mW/cm-K; also five other specimens were measured with intermediate values.	A-7; B-4; C-1; D-1(2); F-3; G-3; O-3; P-2, 4; Q-3; S-1.	G. B. Abdullaev and A. A. Bashshaliev (1957).
. . . . .	. . . . .	Specimens range from pure and 0.0035% Cℓ to 0.25% Cℓ. One was amorphous, two others were crystalline. The three specimens, at 20°C, had a thermal conductivity minimum with a concentration of 0.03% Cℓ; amorphous, k = 6.25 mW/cm-K; crystalline #1, k = 20.5 mW/cm-K; crystalline #2, k = 20.9 mW/cm-K. A maximum exists at 0.25% Cℓ concentration: amorphous, k = 8.3 mW/cm-K; crystalline #1, k = 22.8 mW/cm-K; crystalline #2, k = 25.0 mW/cm-K.	Same as above.	G. M. Aliev and G. B. Abdullaev (1957).

SELENIUM (cont'd)

(See FIGURES 32a and 32b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	99.996% pure.	Continuation of the previous work to 1% Cℓ. Amorphous. At 20°C, thermal conductivity of a specimen with 1% Cℓ concentration: k = 9.45 mW/cm-K.	Same as above.	G. M. Aliev (1957).
. . . . .	99.994% pure.	Amorphous; measured at 26°C, thermal conductivity with various concentrations of I: pure Se, k = 30 mW/cm-K; 0.24%, k = 8.8 mW/cm-K; 1.385%, k = 11.4 mW/cm-K. Crystalline; measured at 26°C, thermal conductivity with various concentrations of I: 0.24%, k = 21.5 mW/cm-K; 1.385%, k = 30 mW/cm-K.	Same as above	G. B. Abdullaev and M. I. Aliev (1957).
W. W. E.-1, 2, 3, 4-Se	#1: > 99.9% pure. #3: Fairmount Chemical. #4: Canadian Copper Refiners; 99.999% pure.	#1: prepared by melting selenium powder in a split brass mold at about 250°C, quenched rapidly in ice water; amorphous. #2: prepared similarly to #1; finely polycrystalline. #3: crystalline. #4: melted powder under a vacuum in a glass tube, chilling melt rapidly to produce solid rods of glassy Se; anneal rods in vacuum for 50-60 hrs. at 210°C to give polycrystalline specimens; ground with emory paper; hexagonal; average grain diameter of about 20μ. One other specimen also measured, with values about 10% lower at temperatures above the conductivity maximum.	A-1; B-1; C-1; D-4(2); E-1,5; F-4; G-3; O-3, 5; P-5.	G. K. White, S. B. Woods, and M. T. Elford (1958).

SELENIUM (cont'd)

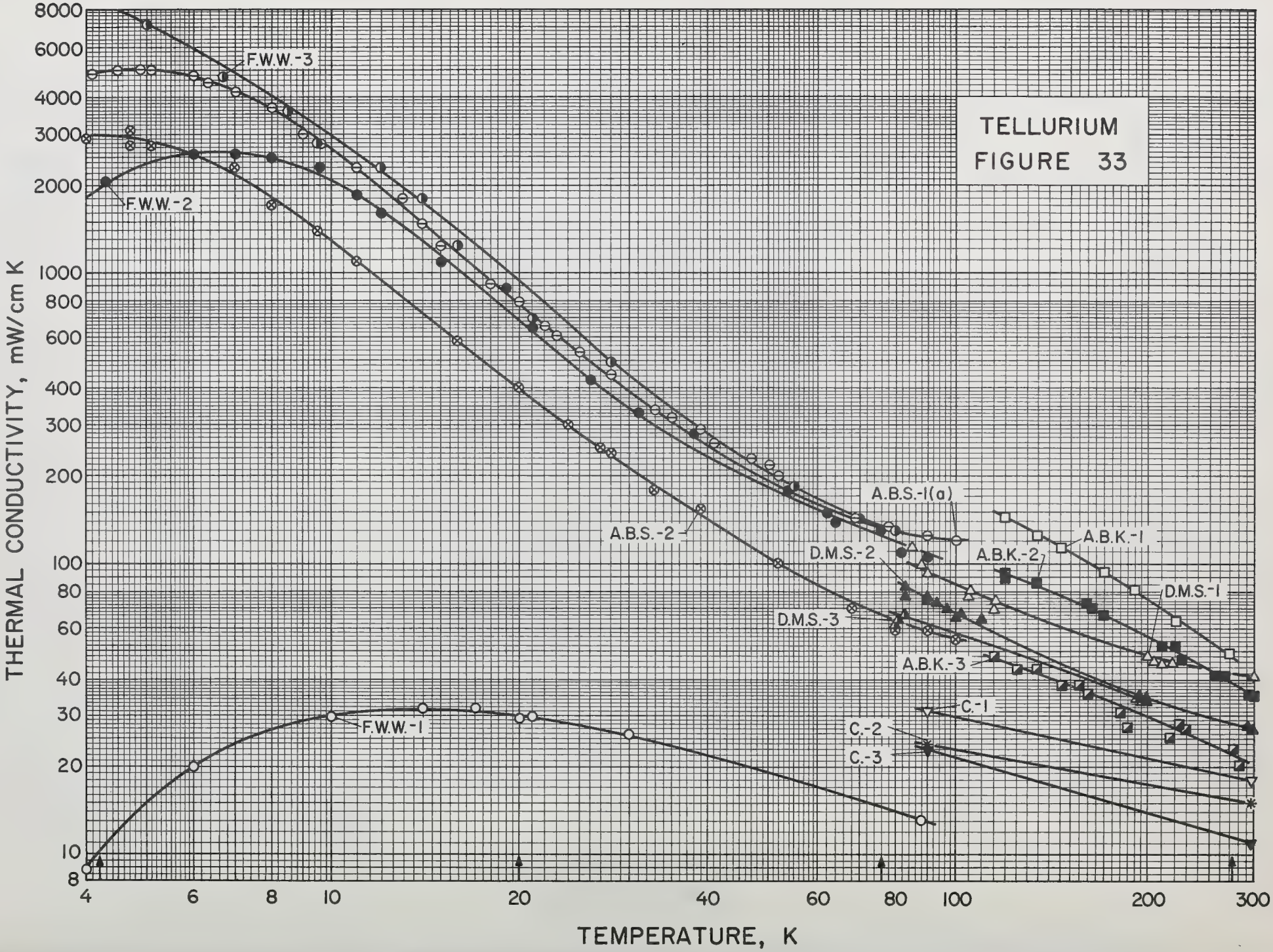
(See FIGURES 32a and 32b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	99.994% starting purity.	Prepared in a vacuum furnace. Amorphous; specimens with different concentrations of Sn and Bi admixtures. At 20°C, the thermal conductivity of pure Se, k = 7.1 mW/cm-K. Thermal conductivity values increase linearly to 1% concentration for: Sn, k = 8.1 mW/cm-K; Bi, 9.6 mW/cm-K. Several specimens of intermediate concentrations also measured. Crystalline; prepared under a pressure of about 100 kg/cm^2 at 200°C for 2 hrs.; specimens with different concentrations of Sn and Bi admixtures. At 20°C, the thermal conductivity of pure Se, k = 19 mW/cm-K. Thermal conductivity values increase linearly to 1% concentration for: Sn, k = 21 mW/cm-K; Bi, k = 24 mW/cm-K. Several specimens of intermediate concentrations also measured. No minima is observed as a function of composition.	A-7; B-4; C-1; D-1(2); F-3; G-3; P-2.	N.A. Aliev and N. I. Ibragimov (1959).
. . . . .	99.996% pure starting material.	Melting together of pure Se and Tl_2Se under vacuum; annealed at 110 and 210°C for 1 hr. Measured at 20°C, thermal conductivity with various concentrations of Tl: pure Se, k = 28 mW/cm-K; 0.05%, k = 13.1 mW/cm-K; 0.5%, k = 20 mW/cm-K; 1.5%, k = 26 mW/cm-K. Several other intermediate concentrations were also measured.	A-7; B-4; C-1; D-1(2); F-3; G-3; O-3; P-2, 4; Q-3; S-1.	G.B. Abdullaev, M.I. Aliev, and S.A. Akhundova (1961).
. . . . .	99.99999% starting purity.	Measured pure specimens and six doped specimens, doped with oxygen-compensating Cd and Sb. Deoxidation of pure Se causes a 15-20% decrease in thermal conductivity.	. . . . .	G.B. Abdullaev, S.I. Mekhtieva, D.Sh. Abdinov, and G.M. Aliev (1965).

SELENIUM (cont'd)

(See FIGURES 32a and 32b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
A.M.A.-1, 2, 3-Se	#1 and #2: 99.9999% pure. #3: 99.99999% pure.	Amorphous; produced from melt by rapid cooling. #1: pure. #2: specimen #1 after heat treatment for 10 hrs.at 373 K. Two other specimens with intermediate annealing times also measured. #3: crystalline; prepared from amorphous phase by annealing in vacuum for 60 hrs. at 210°C. Thermal conductivity measurements at 20°C also made on three specimens doped with various concentrations of Cd; 0.05% (weight), k = 4.1 mW/cm-K; 1%, k = 4.6 mW/cm-K.	A-7; B-4; C-1; D-1(2); F-3; G-3; O-3, 5; P-2, 4, 7; Q-3.	G.B. Abdullaev, S. I. Mekhtieva, D. Sh. Abdinov, G.M. Aliev, and S.G. Alieva (1966).
. . . . .	. . . . .	Amorphous. Measured at 21°C, irradiated by an electron beam with an energy of 5 Mev, for various lengths of time: 0 min., k = 5.0 mW/cm-K; 10 min., k = 6.6 mW/cm-K; 30 min., k = 6.9 mW/cm-K. Measured at 27°C, for the same time lengths, respective values are: k = 5.1 mW/cm-K; k = 6.8 mW/cm-K; k = 6.6 mW/cm-K. Measured at 15°C, with 0.5% (atomic) of various admixtures: Cd, k = 4.5 mW/cm-K; P, k = 1.5 mW/cm-K; Mn, k = 11.3 mW/cm-K. Measured at 26°C, for the same admixtures, respective values are: k = 4.6 mW/cm-K; k = 2.7 mW/cm-K; k = 12 mW/cm-K. Measured at intermediate temperatures, also.	Same as above	G.B. Abdullayev, S. I. Mekhtiyeva, D. Sh. Abdinov, and G.M. Aliyev [sic] (1966).
A.D.A.-1, 2-Se	99.99999% pure.	Single crystals; hexagonal; grown from the melt. #1: rod axis parallel to the hexagonal crystal axis. #2: rod axis perpendicular to the hexagonal crystal axis.	Same as above; O-6; P-4; S-2.	G.B. Abdullayev, N.Z. Dzhalilov, and G.M. Aliyev [sic] (1966).
A.B.S.-1, 2, 3-Se	. . . . .	Single crystals; trigonal. #1: grown from the vapor phase; rod axis parallel to the c-axis. #2: cut from specimen grown from the melt; rod axis parallel to c-axis. #3: cut from specimen grown from the melt; rod axis perpendicular to c-axis. One other specimen also measured.	A-1; B-1; C-1; D-3(2); G-2; O-3, 6; P-3, 4.	A.R. Adams, F. Baumann, and J. Stuke (1967).


TELLURIUM
FIGURE 33
THERMAL CONDUCTIVITY, mW/cm K
TEMPERATURE, K
8000
6000
4000
3000
2000
1000
800
600
400
300
200
100
80
60
40
30
20
10
8
4
6
8
10
20
40
60
80
100
200
300
F.W.W.-3
F.W.W.-2
F.W.W.-1
A.B.S.-1(a)
A.B.S.-2
A.B.K.-1
A.B.K.-2
A.B.K.-3
D.M.S.-1
D.M.S.-2
D.M.S.-3
C.-1
C.-2
C.-3

TELLURIUM

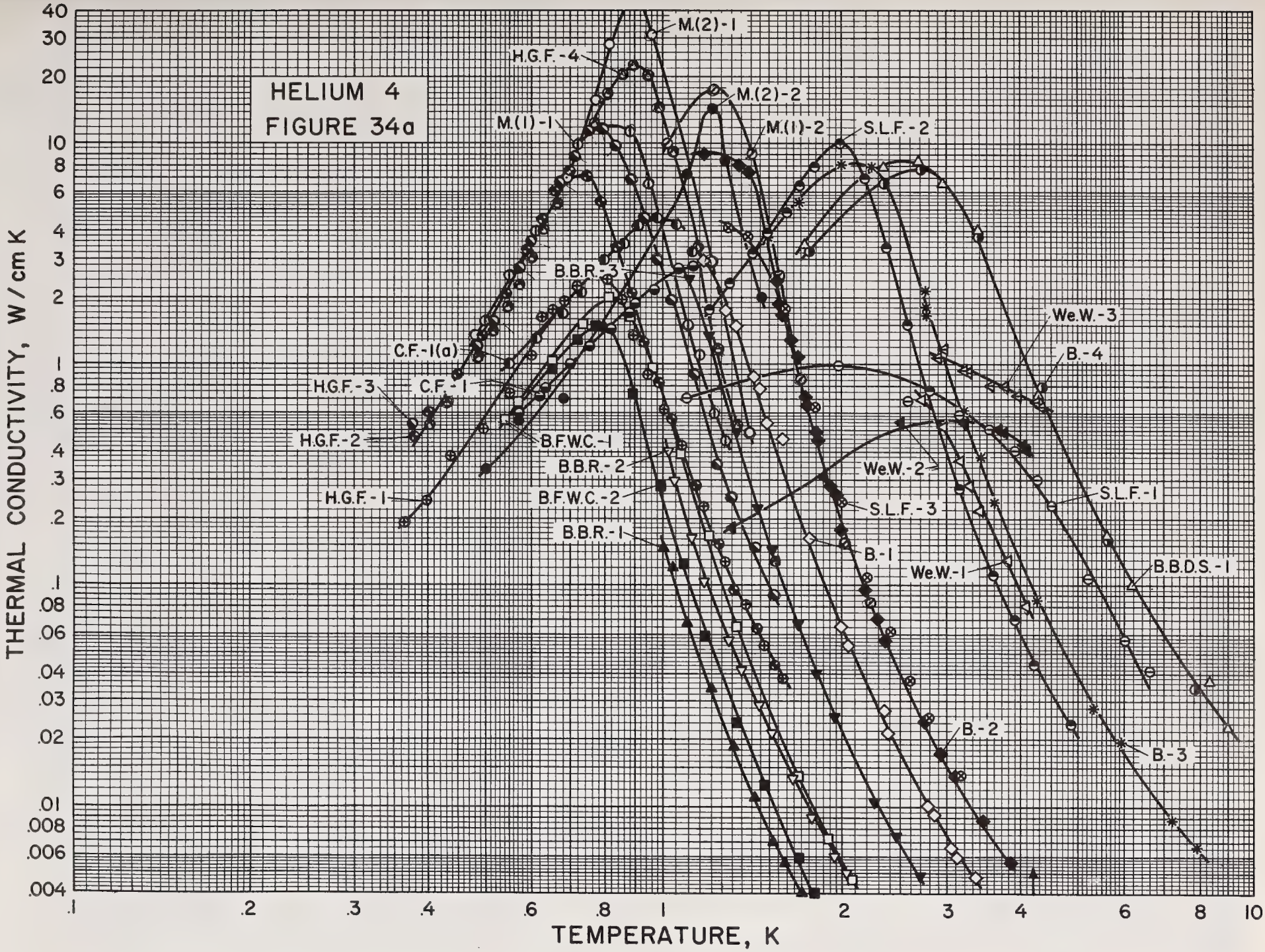
(See FIGURES 32b and 33)

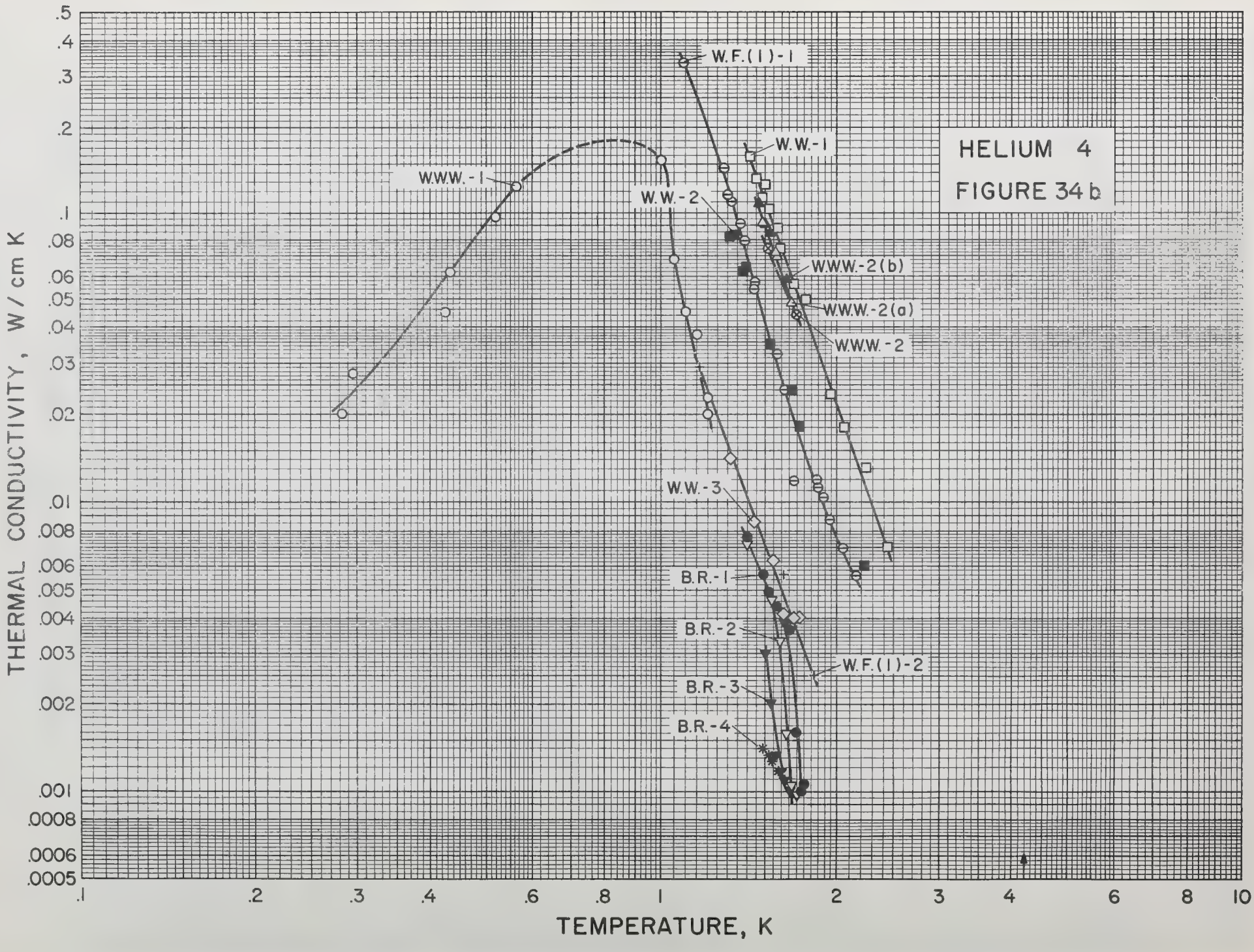
CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
C.-1, 2, 3	< 0.01% impurities. #1 and 2: Univ. of Wisconsin. #3: Riedel de Haën.	Lighted with a 10-W lamp; vacuum distilled and deposited. #1: single crystal; rod axis parallel to crystal axis. #2 and #3: polycrystalline. Table of electronic and lattice components.	A-4; B-4; C-2, 3; D-1(1); F-5; G-3; M-1; O-1; S-1, 2, 5.	C.H. Cartwright (1933).
. . . . .	"Pure".	Small crystallites; cold pressed under 4000 kg/cm^2 and hot pressed at 400°C under 360 kg/cm^2 for 6 hrs; purified by triple fractional distillation in a vacuum. k = 17 mW/cm-K at 10°C. Graph of phonon - and electron-hole conductivities.	A-7; B-4; C-1; D-1(2); F-3; G-3; M-1; O-5; R-1; S-1, 3, 5.	Kh.I. Amirkhanov, G.B. Bagduev, and M. A. Kazhlaev (1957).
F.W.-1, 2, 3-Te	McKay. #1: 99.5% pure. #2: 99.99% pure. #3: 99.99% pure.	#2: prepared by zone refining; individual crystals were 1-2 mm wide and 1 cm long, inclined along the length of the rod. #3: single crystal; zone refined; rod axis inclined 80° to the c-axis. One other specimen also measured.	A-1; B-1; C-1; D-4(2); E-1, 5; F-4; G-1; O-5; P-3, 4, 8; S-1.	G. Fisher, G.K. White, and S.B. Woods (1957).
D.M.S.-1, 2, 3	#1: hole concentration of 10^{15}/cm^3. #2: hole concentration of 9×10^{16}/cm^3. #3: hole concentration of 5×10^{18}/cm^3.	Single crystals; rod axis parallel to the main crystallographic axis. #1: prepared by zone melting, passing specimen through several zone. #2: prepared by recrystallization, achieved by slow cooling in a sealed evacuated ampule of high melting-point glass, Te distilled two and three times serving as the initial material. #3: prepared by recrystallization, slow cooling in an evacuated ampule, with Sb added to the twice-distilled Te.	A-1; B-2; C-1; D-1(4); F-4; G-3; M-1; O-3; R-1, 3; S-1, 2, 5.	E.D. Devyatkova, B. Ya. Moizhes, and I.A. Smirnov (1959).

TELLURIUM (cont'd)

(See FIGURES 32b and 33)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
A.B.K.-1,2,3	. . . . .	Single crystals; grown by slow cooling from 750K to room temperature in a quartz ampoule filled with Te which had been repeatedly purified by zone-melting; cleaved along planes; no separate fine-crystalline inclusions. #1: annealed in vacuum for 24 hrs. at 400K. #2: rod axis parallel to crystallographic axis. #3: rod axis perpendicular to crystallographic axis.	A-7; B-4; C-1; D-1(2); F-3; G-3; O-6; P-4; R-1; S-1.	Kh.I. Amirkhanov, G.B. Bagduev, and M.A. Kazhlaev (1959).
A.B.S.-1,2	. . . . .	Single crystals. #1: grown from the vapor phase; rod axis parallel to the c-axis. #2: cut from a specimen grown from the melt; rod axis perpendicular to the c-axis.	A-1; B-1; C-1; D-3(2); G-2; O-3,6; P-3,4; S-2.	A.R. Adams, F. Baumann, and J. Stuke (1967).


HELIUM 4
FIGURE 34a
THERMAL CONDUCTIVITY, W / cm K
TEMPERATURE, K
40
30
20
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
.01
.008
.006
.004
.1
.2
.3
.4
.6
.8
1
2
3
4
6
8
10
M.(2)-1
H.G.F.-4
M.(2)-2
M.(1)-1
M.(1)-2
S.L.F.-2
B.B.R.-3
We.W.-3
B.-4
C.F.-1(a)
H.G.F.-3
C.F.-1
H.G.F.-2
B.F.W.C.-1
B.B.R.-2
We.W.-2
S.L.F.-1
H.G.F.-1
B.F.W.C.-2
S.L.F.-3
B.B.R.-1
B.-1
We.W.-1
B.B.D.S.-1
B.-2
B.-3


HELIUM 4
FIGURE 34 b
THERMAL CONDUCTIVITY, W / cm K
TEMPERATURE, K
W.F.(1)-1
W.W.-1
W.W.W.-1
W.W.-2
W.W.W.-2(b)
W.W.W.-2(a)
W.W.W.-2
W.W.-3
B.R.-1
B.R.-2
W.F.(1)-2
B.R.-3
B.R.-4
.5
.4
.3
.2
.1
.08
.06
.05
.04
.03
.02
.01
.008
.006
.005
.004
.003
.002
.001
.0008
.0006
.0005
.1
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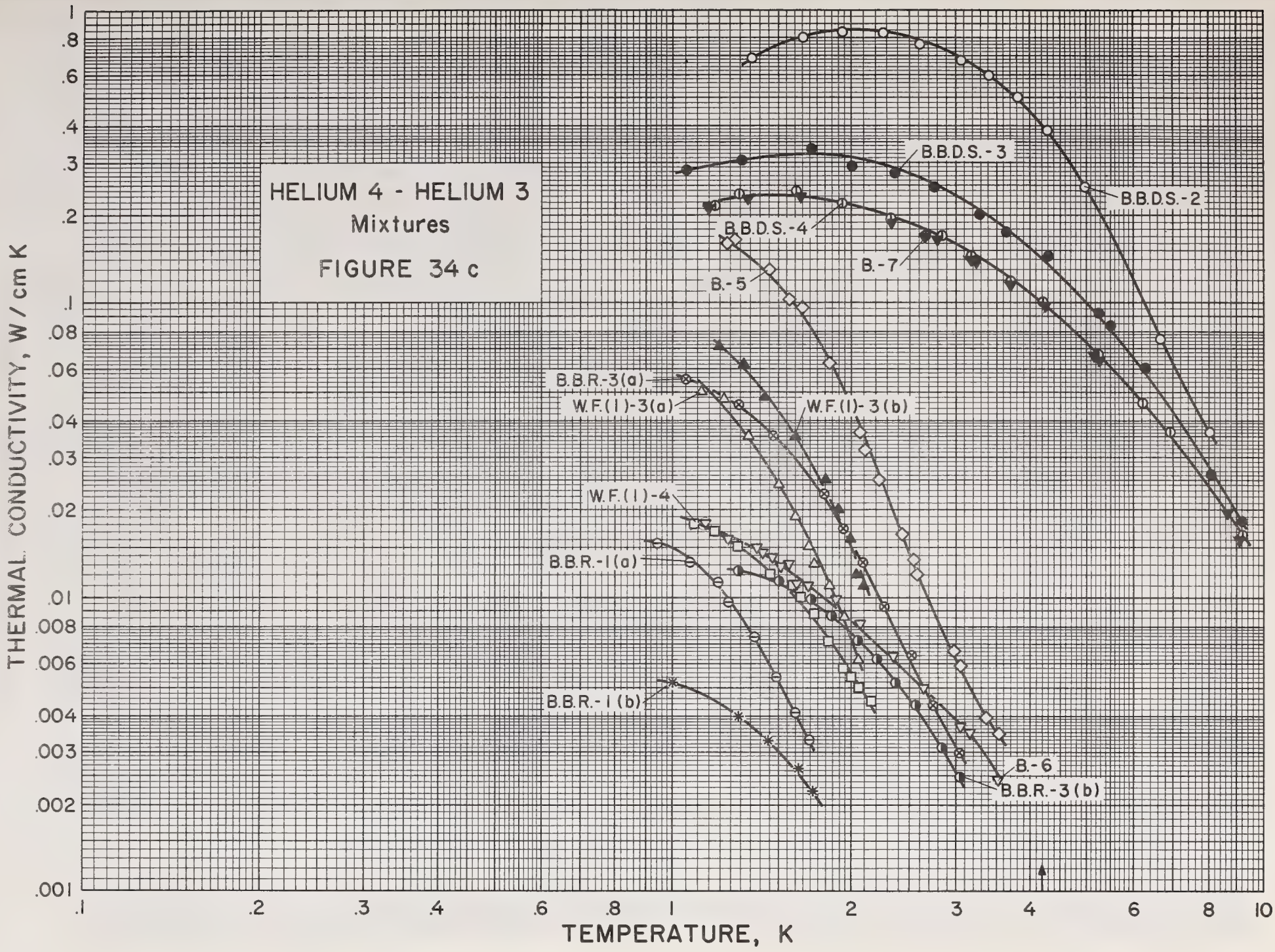
.3
.4
.6
.8
1
2
3
4
6
8
10


HELIUM 4 - HELIUM 3
Mixtures
FIGURE 34 c
THERMAL CONDUCTIVITY, W / cm K
TEMPERATURE, K
B.B.D.S. - 3
B.B.D.S. - 2
B.B.D.S. - 4
B. - 7
B. - 5
B.B.R. - 3(a)
W.F.(1) - 3(a)
W.F.(1) - 3(b)
W.F.(1) - 4
B.B.R. - 1(a)
B.B.R. - 1(b)
B. - 6
B.B.R. - 3(b)
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
.01
.008
.006
.004
.003
.002
.001
.1
.2
.3
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.6
.8
1
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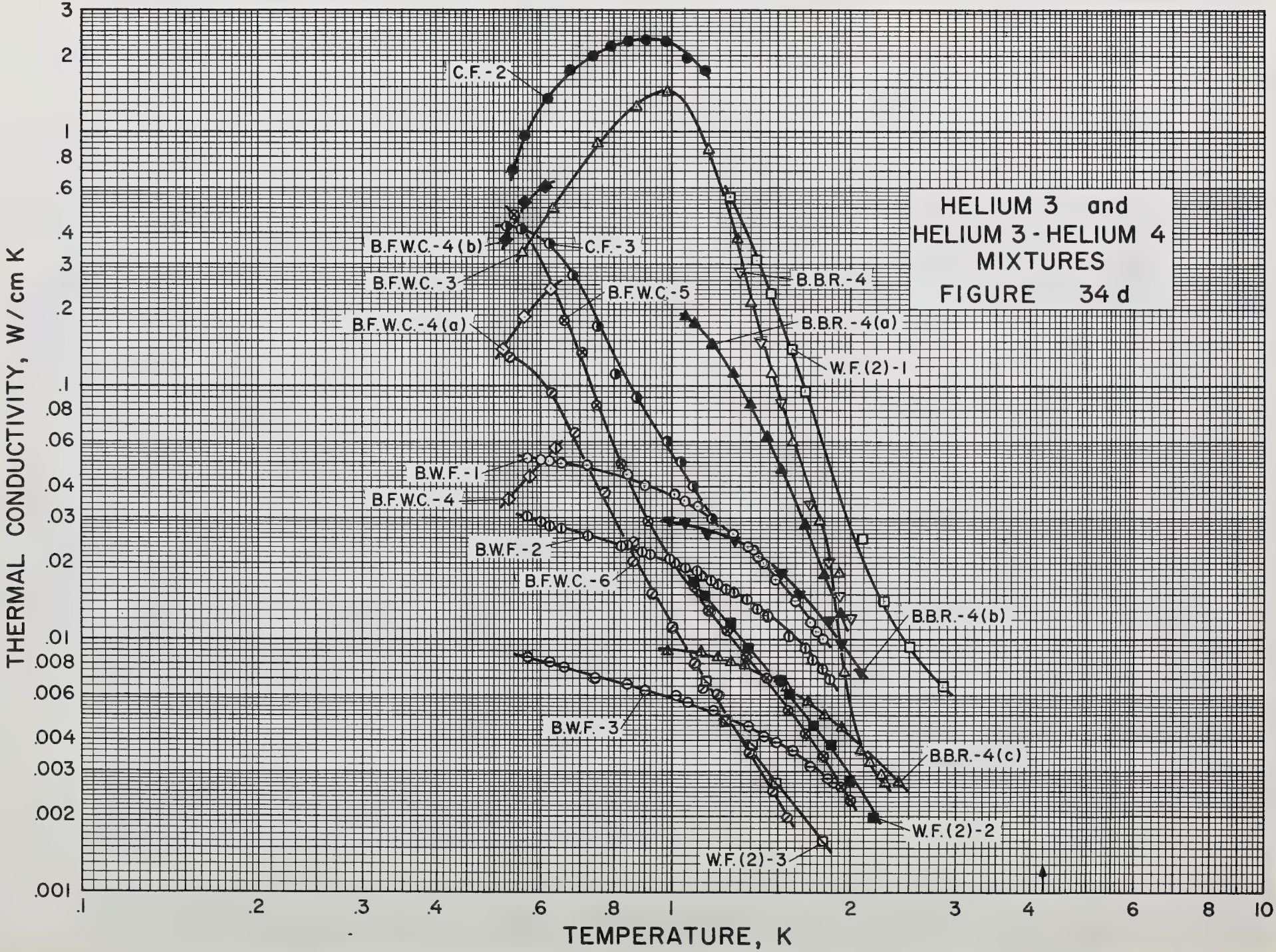
8
10


HELIUM 3 and
HELIUM 3 - HELIUM 4
MIXTURES
FIGURE 34 d
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
C.F.-2
B.F.W.C.-4(b)
C.F.-3
B.F.W.C.-3
B.F.W.C.-5
B.B.R.-4
B.F.W.C.-4(a)
B.B.R.-4(a)
W.F.(2)-1
B.W.F.-1
B.F.W.C.-4
B.W.F.-2
B.F.W.C.-6
B.B.R.-4(b)
B.W.F.-3
B.B.R.-4(c)
W.F.(2)-2
W.F.(2)-3
3
2
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
.01
.008
.006
.004
.003
.002
.001
.1
.2
.3
.4
.6
.8
1
2
3
4
6
8
10

HELIUM
(See FIGURES 34a–34d)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
W.W.-1, 2, 3	. . . . .	Measured He^4 at constant densities whose magnitudes were fixed by the initial pressure and temperature of the liquid. #1: 0.218 g/cm^3. #2: 0.208 g/cm^3. #3: 0.194 g/cm^3. Two other specimens at intermediate densities resulted in intermediate values.	A-1; B-1; C-1; D-2(2); E-5; F-2; G-3; O-3; P-1, 5.	K.R. Wilkinson and J. Wilks (1951).
W.W.W.-1, 2, 2(a), 2(b)	. . . . .	Review and extension of W.W. above; measured He^4 at constant densities. #1: 0.194 g/cm^3; lower temperature measurements on W.W.-3. #2: 0.218 g/cm^3; similar to W.W.-1 but lower in value because measurements were made in a narrower tube. Specimen #2 was then annealed at: 2.3 K (a); 2.7 K (b).	A-1; B-1; C-1; D-2(2), 3(2), 6(1); E-5; F-2; G-3; O-3, 5.	F.J. Webb, K.R. Wilkinson, and J. Wilks (1952).
We.W.-1, 2, 3	. . . . .	Extension of W.W.W. above; measured He^4 at constant densities with two size specimen-tubes. #1: 0.294 g/cm^3; 2.6 mm i.d. tube. #2: 0.336 g/cm^3; 0.5 mm i.d. tube. #3: 0.345 g/cm^3; 2.6 mm i.d. tube. Also measured at seven other densities.	A-1; B-3; C-1; D-3(4); F-4; G-2; O-3, 5; P-1, 5.	F.J. Webb and J. Wilks (1953).
W.F.(1)-1, 2, 3(a), 3(b), 4	. . . . .	Measured at constant densities. #1: He^4, 0.208 g/cm^3 at 96 atm. pressure. #2: He^4, 0.194 g/cm^3 at 56.2 atm. pressure. #3: He^4- He^3 solid mixture containing 0.56% (atomic) He^3 at densities and starting pressures of: (a), 0.208 g/cm^3 and 96 atm; (b), 0.218 g/cm^3 and 131 atm. #4: He^4- He^3 solid solution for a concentration of 2.80% (atomic) He^3 at a density of 0.208 g/cm^3 and a pressure of 96 atm. Another intermediate concentration was measured, with intermediate values.	A-1; B-2; C-1; D-3(5); E-5; F-4; G-2; O-3; P-2, 3, 5, 8.	E.J. Walker and H.A. Fairbank (1960a).

HELIUM (cont'd)

(See FIGURES 34a–34d)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
W.F.(2)-1, 2, 3	. . . . .	He^3; measured at constant densities. #1: 0.1615 g/cm^3, hexagonal close-packed structure. #2: 0.150 g/cm^3, body-centered cubic. #3: 0.140 g/cm^3, body-centered cubic. Three other intermediate densities were also measured.	A-1; B-1; C-1; D-3(5); E-5; F-4; G-2; O-3.	E. J. Walker and H. A. Fairbank (1960b, 1961).
C.F.-1, 1(a), 2, 3	. . . . .	#1: He^4; measured at constant density of 0.218 g/cm^3; existing in hcp structure; prepared by cooling fairly rapidly to 0.5 K. #1(a): annealed by raising the temperature to about 2 K for ~ 30 min, slowly cooled to 0.5 K. #2: He^3; density of 0.155 g/cm^3; hcp structure; annealed similar to #1(a) to 2.10 K. #3: He^3; density of 0.150 g/cm^3; bcc structures; annealed similar to #1(a) to 2.35 K.	A-1; B-1; C-1; D-3(5); E-5; F-4; G-2.	M. J. Crooks and H. A. Fairbank (1963).
M.(1)-1, 2	"High degree of perfection".	He^4; grown in a glass ampoule at constant pressures. #1: grown at 82 atm for 1.5 hrs; 2.5 mm diameter. #2: 185 atm, 2.5 mm diameter. Both specimens annealed near the melting point.	For apparatus, see Mezhov-Deglin (1965).	L. P. Mezhov-Deglin (1964).
B.R.-1, 2, 3, 4	. . . . .	He^4; measured at constant densities. #1: 0.1913 g/cm^3; solid existing as hcp, as a mixed phase, and as bcc, with decreasing temperature. #2: 0.1911 g/cm^3; solid existing same as #1. #3: 0.1905 g/cm^3; solid existing as mixed and bcc. #4: 0.1900 g/cm^3; solid existing as bcc. Also measured specimens at two other densities.	A-1; B-1; C-1; D-1(3); E-5; F-4; G-2; O-2, 3; P-5.	R. Berman and S. J. Rogers (1964, 1965).
B.W.F.-1, 2, 3	. . . . .	He^3-rich mixtures at 15.4 g/cm^3. #1: He^3-1.3% He^4. #2: He^3-4.0% He^4. #3: He^3-50% He^4.	A-1; B-1; C-1; D-3(3); E-5; F-4; G-2; P-8.	R. Bertman, C. W. White and H. A. Fairbank (1965).

HELIUM (cont'd)

(See FIGURES 34a–34d)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
B.B.R.-1, 1(a), 1(b), 2, 3, 3(a), 3(b), 4, 4(a), 4(b), 4(c)	. . . . .	Isotopic mixtures of He^3 and He^4, condensed in stainless-steel tube of 5.5 mm i.d., at different fixed pressures of formation such that the solid has a hcp lattice. He^4-rich mixture at 60 atm filling pressure: #1, pure; #1(a), 1.22% He^3; #1(b), 11.1% He^3; also one other intermediate specimen. He^4 at 90 atm filling pressure: #2, pure; also three other specimens measured. He^4-rich mixture at 140 atm filling pressure: #3, pure; #3(a), 1.22% He^3; #3(b), 11.1% He^3; also one other intermediate specimen. He^3-rich mixture at 145 atm filling pressure: #4, pure; #4(a), 0.117% He^4; #4(b), 1.7% He^4; #4(c), 16.0% He^4; also three other specimens measured.	A-1; B-1; C-1; D-1(3); E-5; F-4; G-2; O-2, 3; P-5, 8, 9.	R. Berman, C.L. Bounds, and S.J. Rogers (1965); also R. Berman, C.L. Bounds, J. C.F. Brock, and S.J. Rogers (1965).
M.(2)-1, 2	. . . . .	α-He^4, hcp; single crystals grown in a glass vial at constant pressure; helium was purified by means of a super leak. #1: grown at 85 atm, annealed; maximum at 0.9 K of 50. #2: grown at 185 atm. Both have low concentration of lattice defects. Eleven other crystals of 85 atm and seven other crystals of 185 atm were measured, Thermal conductivity of the upper and lower parts of specimens were measured.	A-1; B-1; C-1; D-3(3); F-4; G-3; O-3, 5, 8; P-1, 4, 5.	L.P. Mezhov-Deglin (1965, 1967).

HELIUM (cont'd)

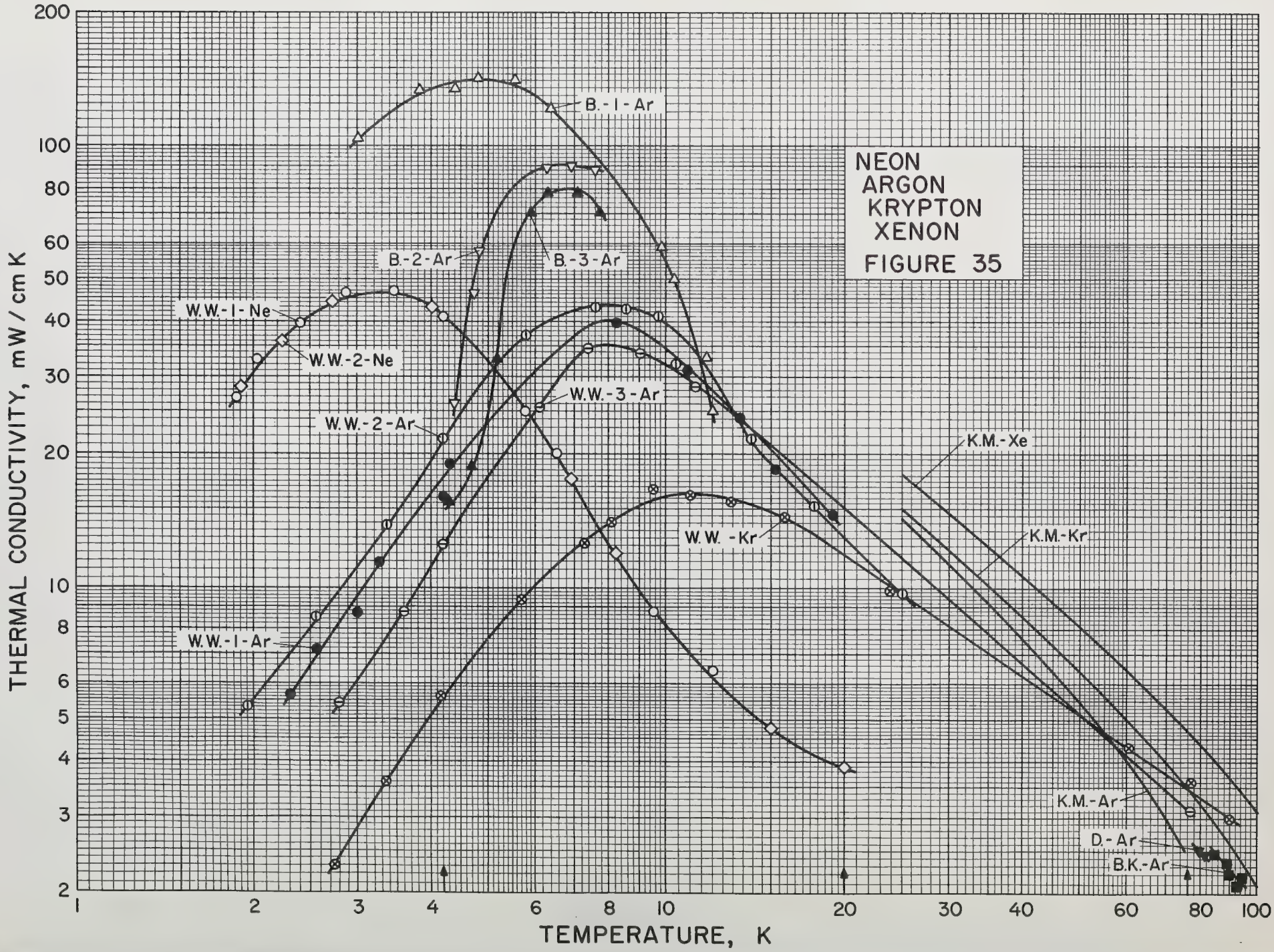
(See FIGURES 34a–34d)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
B.F.W.C.-1, 2, 3, 4, 4(a), 4(b), 5, 6	. . . . .	He^3 and He^4, measured at constant volume; condensed at constant volume in a stainless-steel tube of 2.0 mm i.d. Annealed at a temperature within the liquid-solid mixed-phase (2-3 K) for 30 min; cooled slowly to 1.1 K in 90 min., and then slowly cooled to 0.5 K. #1: He^4 at 0.205 g/cm^3, in the hcp phase. #2: He^4 at 0.198 g/cm^3, in the hcp phase. #3: He^3 at 0.154 g/cm^3, in the hcp phase. #4: He^3, unannealed. #4(a): He^3, annealed below the mixed-phase region. #4(b): annealed in the mixed-phase region. Specimen #4 was in the bcc phase; unspecified density. #5: He^3 at 0.149 g/cm^3, in the bcc phase. #6: He^3 at 0.139 g/cm^3, in the bcc phase.	A-1; B-1; C-1; D-3(3); E-5; F-4; G-2; O-3, 5, 6; P-5.	B. Bertman, H.A. Fairbank, C.W. White, and M.J. Crooks (1966).
B.B.D.S.-1, 2, 3, 4	. . . . .	Isotopic mixtures of He^4 and He^3, solidified at constant volume. #1: He^4, pure; freezing pressure of 1725 atm. #2: He^4-0.42% He^3. #3: He^4-3.2% He^3. #4: He^4-8% He^3. #2-#4: freezing pressures varied from 1697-1725 atm. One other specimen of intermediate volume was measured.	A-1; B-1; C-1; D-1(3); E-5; F-4; G-2; O-2, 3; P-5, 8, 9.	R. Berman, C.L. Bounds, C.R. Day, and H.H. Sample (1968); see also Berman and Day (1970).
S.L.F.-1, 2, 3	Matheson; < 4 ppm chemical impurities. #1 and #3: not repurified; #2: repurified.	He^4, in the hcp phase; condensed at constant pressures; specimen diameter of: #1, 2.1 mm; #2 and #3, 2.2 mm. Measured at different molar volumes. #1: 0.328 g/cm^3, no repurification. Grown at 1050 atm for 8 hrs. #2: 0.286 g/cm^3. Grown 486 atm for 2.2 hrs. #3: 0.244 g/cm^3, no repurification. Grown at 188 atm for 8 hrs. Fourteen other specimens at intermediate densities had intermediate results. Thermal conductivity also determined for lower and upper portions of specimens.	A-1; B-1; C-1; D-3(3); E-3; F-4; G-2; O-2, 3, 5, 6, 8; P-2, 5.	W.D. Seward, D. Lazarus, and S.C. Fain, Jr. (1969).

HELIUM (cont'd)

(See FIGURES 34a–34d)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
H.G.F.-1, 2, 3, 4	. . . . .	He^4, single crystals; hcp phase; solidified at constant pressure; annealed for 3 hrs; measured at different inclinations. #1: grown at a pressure of 85 atm at a rate of 3 cm/hr. Specimen diameter 0.1773 cm. Rod axis parallel to the c-axis. #2: grown at a pressure of 85 atm at a rate of 1.3 cm/hr. Specimen diameter 0.2682 cm. Rod axis inclined 7° ± 4° to the c-axis. #3: grown at a pressure of 85 atm at a rate of 2.2 cm/hr. Specimen diameter 0.2682 cm. Rod axis inclined 61° ± 2° to the c-axis. #4: grown at a pressure of 85 atm at a rate of 3.5 cm/hr. Specimen diameter 0.2682 cm. Rod axis inclined 90° to the c-axis. Five other specimens were also measured.	A-1; B-1; C-1; D-3(3); E-5; F-4; G-2; O-2, 3, 5, 6, 8; P-5.	E.M. Hogan, R.A. Guyer, and H.A. Fairbank (1969).
B.-1, 2, 3, 4, 5, 6, 7	. . . . .	He^4, at different freezing temperatures. #1: 190 atm. #2: 250 atm. #3: 800 atm. #4: 1725 atm. Two other specimens were also measured. #5: He^4-0.26% He^3; θ_D = 43.0 K. #6: He^4-16.25% He^3; θ_D = 43.0 K. #7: He^4-8.0% He^3; θ_D = 104 K. Other specimens at different concentrations and θ_D were also measured.	. . . . .	R. Berman (1969, 1970).


NEON
ARGON
KRYPTON
XENON
FIGURE 35
THERMAL CONDUCTIVITY, mW / cm K
TEMPERATURE, K
B.-1-Ar
B.-2-Ar
B.-3-Ar
W.W.-1-Ne
W.W.-2-Ne
W.W.-3-Ar
W.W.-2-Ar
W.W.-Kr
W.W.-1-Ar
K.M.-Xe
K.M.-Kr
K.M.-Ar
D.-Ar
B.K.-Ar
200
100
80
60
50
40
30
20
10
8
6
5
4
3
2
1
2
3
4
6
8
10
20
30
40
60
80
100

NEON

(See FIGURE 35)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
W.W.-1, 2-Ne	#1: Linde Air Products; 99.96% pure. #2: Air Reduction; < 0.1% contaminants.	Condensed the gas in a thin walled Inconel tube of 9.5 mm diameter.	A-1; B-1; C-1; D-4(2); E-5; F-4; G-2; O-3, 5.	G.K. White and S. B. Woods (1958c).

ARGON
(See FIGURE 35)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
W. W. -1, 2, 3-Ar	#1: Linde Air Products; commercial purity. #2: Air Reduction; "high purity". #3: Matheson; "high purity". All assumed to have < 0.1% contaminants.	Condensed the gas in a thin walled Inconel tube of 9.5 mm diameter.	A-1; B-1; C-1; D-4(2); E-5; F-4; G-2; O-3, 5.	G. K. White and S. B. Woods (1956a, 1958c); also see G. K. White, S. B. Woods, and D. K. C. MacDonald (1956).
. . . . .	"Commercial".	Condensed in a glass tube. k = 2.6 ± 0.4mW/cm-K at 80 K.	A-8; B-1; C-2; D-1, 5(2); E-5; F-4; G-3.	D. J. Lawrence, A. T. Stewart, and E. W. Guptill (1959).
. . . . .	. . . . .	Thermal conductivity of a probably solid specimen was measured during runs on the gas at high pressures.	. . . . .	L. D. Ikenberry and S. A. Rice (1963).
B. -1, 2, 3-Ar	99.6% Ar^{40}; 0.34% Ar^{36}. #1: 1.6×10^{-4}% N_2. #2 and #3: 1.4×10^{-3}% N_2.	Prepared by the Bridgman method; grown in Pyrex tube for 28 hrs; later removed from tube; 0.5 cm diameter. #1: slightly opaque on the surface; clear at liquid helium temperatures. #2: slightly opaque on the surface. #3: specimen #2, heated at 30 K and recooled. Another specimen was measured spectroscopically; clear specimen with 10^{-5} % N_2; k = 550 mW/cm-K at 4.8 K; k = 600 mW/cm-K at 5 K; k = 620 mW/cm-K at 5.2 K; k = 210 mW/cm-K at 86 K.	A-1; B-1; C-1; D-4(2); F-4; G-3; O-5; P-4.	G. Boato (1964).
B. K. -Ar	99.95% pure.	Pressure of 500 kgf/cm^2 measured near solidification line.	A-8; B-1; C-1; D-1(6); E-2; F-2; G-3; O-1.	B. J. Bailey and K. Kellner (1968).
K. M. -Ar	99.9% pure.	Grown from vapor phase; no visible defects; transparent; 1-5 mm grains.	A-1; B-1; C-1; D-1(2); E-2; F-2; G-3; O-3, 10.	I. N. Krupskii and V. G. Manzhelii (1969).
D. -Ar	99.996% pure.	3 mm diameter grains.	A-3; B-1; C-1; D-1(2); E-5; F-4; G-3; O-3.	D. E. Daney (1971).

KRYPTON

(See FIGURE 35)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
W. W. -Kr	Linde Air Products; 99.96% purity.	Condensed the gas in a thin walled Inconel tube of 9.5 mm diameter. Specimen was annealed at 90 K and 77 K for some hours and at 55 K for about 15 hrs; two other unannealed specimens had the same results.	A-1; B-1; C-1; D-4(2); E-5; F-4; G-2; O-3, 5.	G. K. White and S. B. Woods (1958c).
. . . . .	. . . . .	Thermal conductivity of a probably solid specimen was measured during runs on the gas at high pressure.	. . . . .	L. D. Ikenberry and S. A. Rice (1963).
K. M. -Kr	99.9% pure.	Grown from the vapor phase; no visible defects; transparent; 1-5 mm grains.	A-1; B-1; C-1; D-1(2); E-2; F-2; G-3; O-3, 10.	I. N. Krupskii and V. G. Manzhelii (1969).

XENON

(See FIGURE 35)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	Thermal conductivity of a probably solid specimen was measured during runs on the gas at high pressure.	. . . . .	L. D. Ikenberry and S. A. Rice (1963).
K. M. -Xe	99.9% pure.	Grown from vapor phase; no visible defects; transparent; 1-5 mm grains.	A-1; B-1; C-1; D-1(2); E-2; F-2; G-3; O-3, 10	I. N. Krupskii and V. G. Manzhelii (1969).

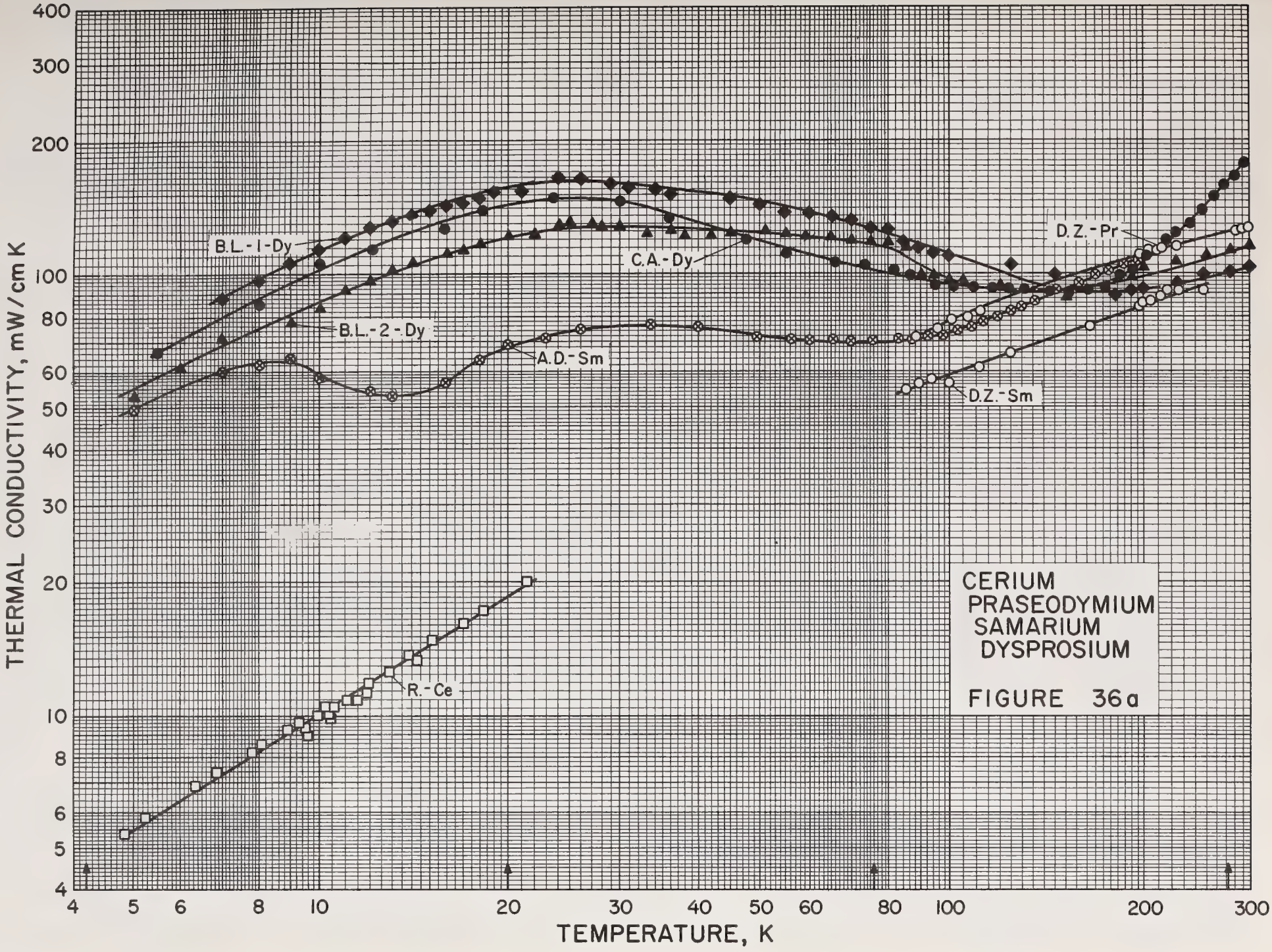
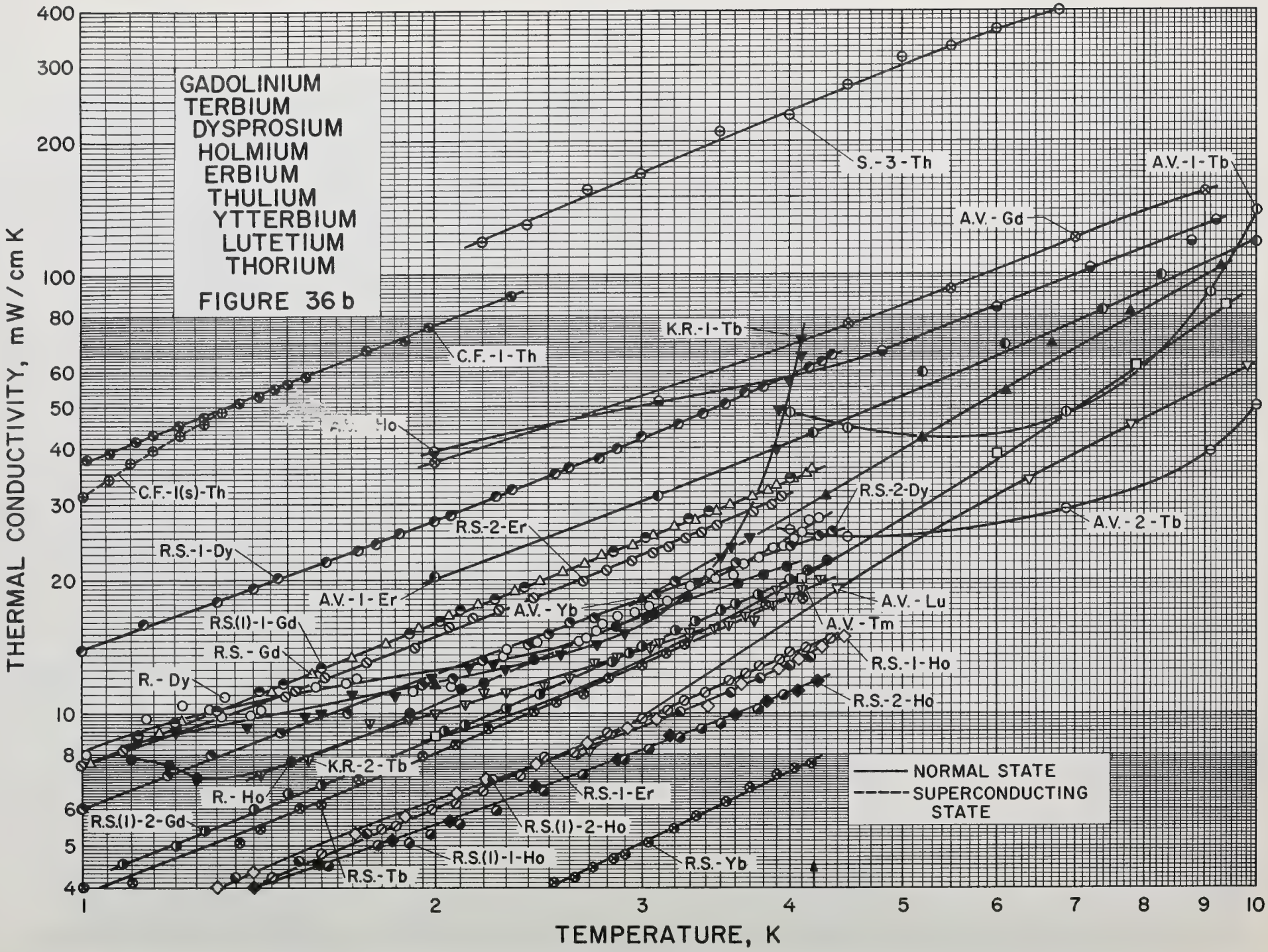

THERMAL CONDUCTIVITY, mW/cm K
TEMPERATURE, K
400
300
200
100
80
60
50
40
30
20
10
8
6
5
4
4
5
6
8
10
20
30
40
50
60
80
100
200
300
B.L.-1-Dy
B.L.-2-Dy
C.A.-Dy
D.Z.-Pr
A.D.-Sm
D.Z.-Sm
R.-Ce
CERIUM
PRASEODYMIUM
SAMARIUM
DYSPROSIUM

FIGURE 36a


GADOLINIUM
TERBIUM
DYSPROSIUM
HOLMIUM
ERBIUM
THULIUM
YTTERBIUM
LUTETIUM
THORIUM
FIGURE 36 b
THERMAL CONDUCTIVITY, mW/cm K
TEMPERATURE, K
400
300
200
100
80
60
50
40
30
20
10
8
6
5
4
1
2
3
4
5
6
7
8
9
10
S.-3-Th
A.V.-1-Tb
A.V.-Gd
K.R.-1-Tb
C.F.-1-Th
C.F.-1(s)-Th
R.S.-2-Dy
R.S.-2-Er
R.S.-1-Dy
A.V.-2-Tb
A.V.-1-Er
A.V.-Yb
A.V.-Lu
A.V.-Tm
R.S.(I)-1-Gd
R.S.-Gd
R.-Dy
R.S.-1-Ho
R.S.-2-Ho
K.R.-2-Tb
R.-Ho
R.S.-1-Er
R.S.(I)-2-Gd
R.S.(I)-2-Ho
R.S.(I)-1-Ho
R.S.-Tb
R.S.-Yb
NORMAL STATE
SUPERCONDUCTING STATE

CERIUM
(See FIGURE 36a)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
R.-Ce	Ames Laboratory; 99.6% pure; greatest impurities are Mg and Ca; RRR(20) = 1.93.	. . . . .	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1; M-1; S-1.	H.M. Rosenberg (1955).
. . . . .	Johnson, Matthey; ~ 0.02% other base metals; < 0.01% other rare-earth metals.	Reduced in vacuum in tantalum crucibles from its fluoride; remelted in vacuum. At 291 K, k = 112 mW/cm-K, average value obtained by two-ball and direct reading thermal comparator methods.	A-6; B-2; D-1(2); F-5; G-3; S-1, 5.	B.W. Jolliffe, R. P. Tye, and R. W. Powell (1966); also R.W. Powell and B.W. Jolliffe (1965).

PRASEODYMIUM
(See FIGURE 36a)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
D.Z.-Pr	0.5% La; 0.04% Cu; 0.03% Fe; 0.01% Ca.	Briquetted powder under 8000 kg/cm^2 pressure, annealed in vacuum for 1-2 hrs at 1600-1800°C. Hexagonal, La-type structure.	A-6; B-1; C-1; D-1(4); E-1; F-4; G-3; L-1; M-1; O-3; Q-1; S-1, 2, 5.	E.D. Devyatkova, V.P. Zhuze, A. V. Golubkov, V. M. Sergeeva, and I.A. Smirnov (1964).
. . . . .	Johnson, Matthey; ~ 0.1% Ta; < 0.1% other rare-earth metals; ~ 0.02% other base metals.	Reduced in vacuum in tantalum crucibles from its fluoride; remelted in vacuum. At 291 K, k = 120 mW/cm-K, obtained by the direct reading thermal comparator.	A-6; B-2; D-1(2); F-5; G-3; S-1, 5.	B.W. Jolliffe, R. P. Tye, and R. W. Powell (1966).

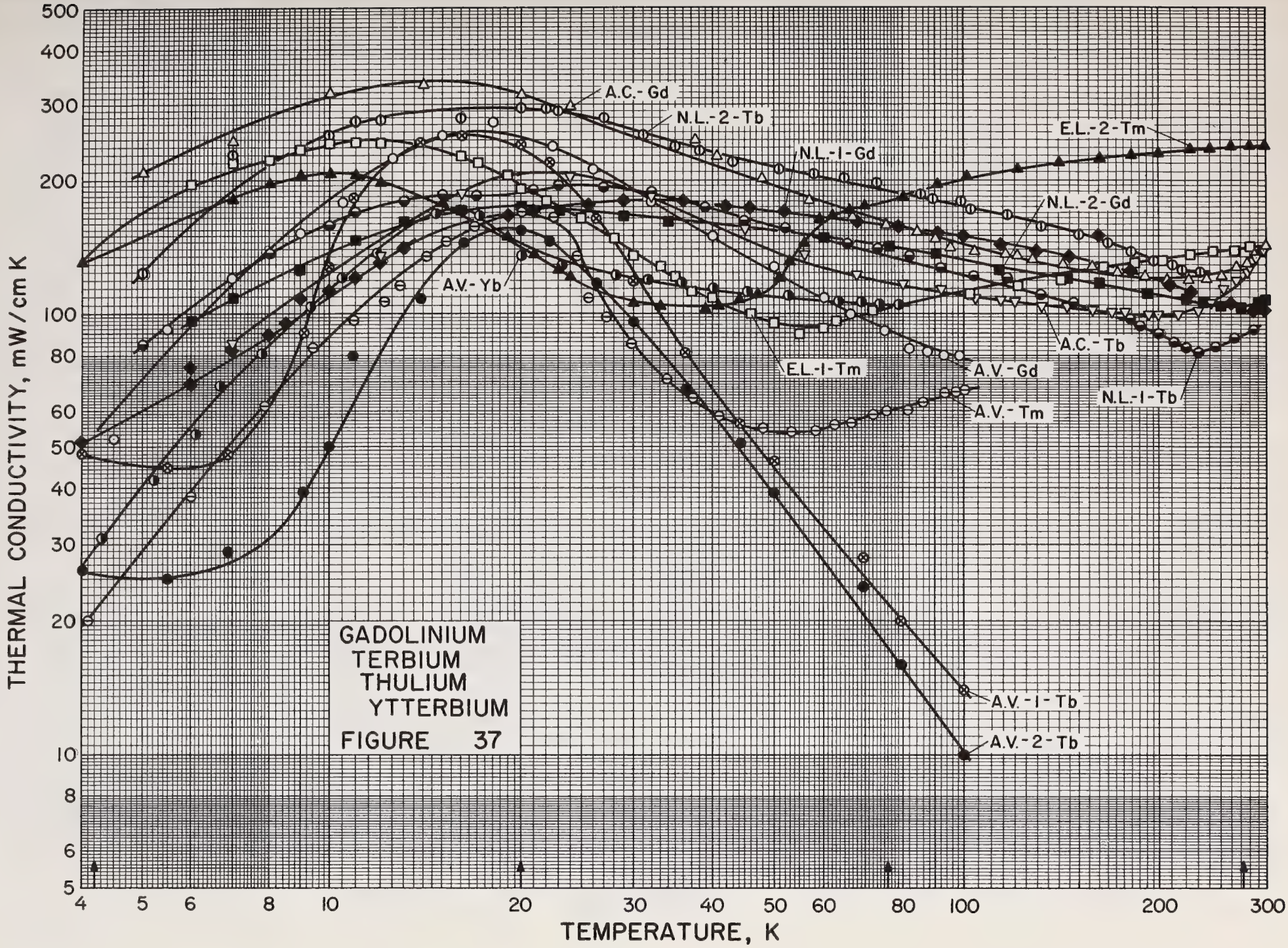
NEODYMIUM

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	Johnson, Matthey; ~0.1% Ta; <0.1% other rare-earth metals; ~0.02% other base metals.	Reduced in vacuum in tantalum crucibles from its fluoride; remelted in vacuum. At 291 K, k = 165 mW/cm-K, average value obtained by two-ball and direct reading thermal comparator methods.	A-6; B-2; D-1(2); F-5; G-3; S-1, 5.	B.W. Jolliffe, R.P. Tye, and R.W. Powell (1966); also R.W. Powell and B.W. Jolliffe (1965).

SAMARIUM

(See FIGURE 36a)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
D.Z.-Sm	"High purity"; 0.5% Eu; 0.18% Ca; 0.02% Gd; 0.01% Nd and Y.	Briquetted powders under 8000 kg/cm^2 pressure, annealed in vacuum for 1-2 hrs at 1600-1800°C. Rhombohedral structure.	A-6; B-1; C-1; D-1(4); E-1; F-4; G-3; L-1; M-1; O-3; Q-1; S-1, 2, 5.	E.D. Devyatkova, V.P. Zhuze, A. V. Golubkov, V. M. Sergeeva, and I.A. Smirnov (1964).
A.D.-Sm	Research Chemicals; 0.05% Eu; 0.02% Ca; 0.01% Gd and Mg; and 0.005% Si; RRR = 13.	Arc melted for 10 minutes under 100 mm pressure in Ar atmosphere; machined.	A-1; B-1; C-1; D-1(2); E-1; F-4; G-2; L-1; M-1; N-6; R-2; S-1, 5.	S. Arajs and G.R. Dunmyre (1965).
. . . . .	Johnson, Matthey; < 0.1% other rare-earth metals; ~ 0.02% other base metals.	Reduced from its oxide with lanthanum; sublimed in vacuum and unlikely to contain tantalum. At 291 K, k = 134 mW/cm-K, average value obtained by two-ball and direct reading thermal comparator methods.	A-6; B-1; D-1(2); F-5; G-3; S-1, 5.	B.W. Jolliffe, R. P. Tye, and R. W. Powell (1966); also R.W. Powell and B.W. Jolliffe (1965).


THERMAL CONDUCTIVITY, mW/cm K
TEMPERATURE, K
500
400
300
200
100
80
60
50
40
30
20
10
8
6
5
4
5
6
8
10
20
30
40
50
60
80
100
200
300
A.C.- Gd
N.L.-2-Tb
N.L.-1-Gd
E.L.-2-Tm
N.L.-2-Gd
A.V.- Yb
A.C.- Tb
E.L.-1-Tm
A.V.- Gd
N.L.-1-Tb
A.V.- Tm
A.V.- 1- Tb
A.V.- 2- Tb
GADOLINIUM
TERBIUM
THULIUM
YTTERBIUM
FIGURE 37

GADOLINIUM

(See FIGURES 36b and 37)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
A.C.-Gd	Research Chemicals; < 0.1% (weight) O_2; 0.04% Y; 0.01% Ca, Mg, and Si; 0.002% Al and Cu; trace of Eu.	Arc-melted; swaged; wrapped in tantalum foil, sealed in silica capsule containing argon at 15 cm Hg at 300 K, annealed for 48 hrs at 800 K, furnace cooled to 300 K in about 10 hrs.	A-1; B-1; C-1; D-1(2); E-1; F-4; G-2; L-1; M-1; N-6; R-2; S-1, 5.	S. Arajs and R. V. Colvin (1964).
. . . . .	Johnson, Matthey; ~ 0.1% Ta; < 0.1% other rare-earth metals; ~ 0.02% other base metals.	Reduced in vacuum in tantalum crucibles from its fluoride; remelted in vacuum. At 291 K, k = 91 mW/cm-K, average value obtained by two-ball and direct reading thermal comparator methods.	A-6; B-1; D-1(2); F-5; G-3; S-1, 5.	B.W. Jolliffe, R.P. Tye, and R.W. Powell (1966); also R.W. Powell and B.W. Jolliffe (1965).
A.V.-Gd	99.9% pure; RRR(20) = 47.4.	Annealed in helium atmosphere for $1\frac{1}{2}$ hrs at 650°C.	A-1; B-4; C-1; D-3(2); E-3, 5; G-3; L-1; M-1; S-5.	N.G. Aliev and N. V. Volkenshtein (1966a).
. . . . .	Johnson, Matthey.	Specimen remeasured by Ratnalingam and Sousa below.	. . . . .	A.G. Karagyozyan and K.V. Rao (1967).
R.S.-Gd	Same specimen as K.R. above.	. . . . .	A-1; B-1; C-1; D-3(2); E-5; G-2; L-1; M-1; R-2.	R. Ratnalingam and J.B. Sousa (1969 b).
N.L.-1, 2-Gd	< 500 ppm (weight) Ho and Tb; 218 ppm O_2; < 200 ppm Dy and Ta; < 20 ppm Fe and Ni. #1: RRR(27) = 31.4. #2: RRR(27) = 46.8.	Single crystals; rectangular parallelepiped; hcp; grown by the strain-anneal method; mechanically polished, etched, and electropolished. #1: rod axis parallel to $[11\bar{2}0]$ direction. #2: rod axis parallel to [0001] direction. Table of electronic component.	A-1; B-1; C-1; D-1(2); E-8; F-4; G-2; L-1, 2; M-1; N-4, 6; S-1, 5.	W.J. Nellis and S. Legvold (1969).
R.S.(1)-1, 2-Gd	#1: RRR(27) = 44.3. #2: RRR(27) = 22.3.	#1: wire. #2: thin slab. Also measured effect of cold working on #2.	A-1; B-4, 5; C-1; D-3(2); E-5; F-4; G-3; M-2, 3; Q-1.	R. Ratnalingam and J.B. Sousa (1971).

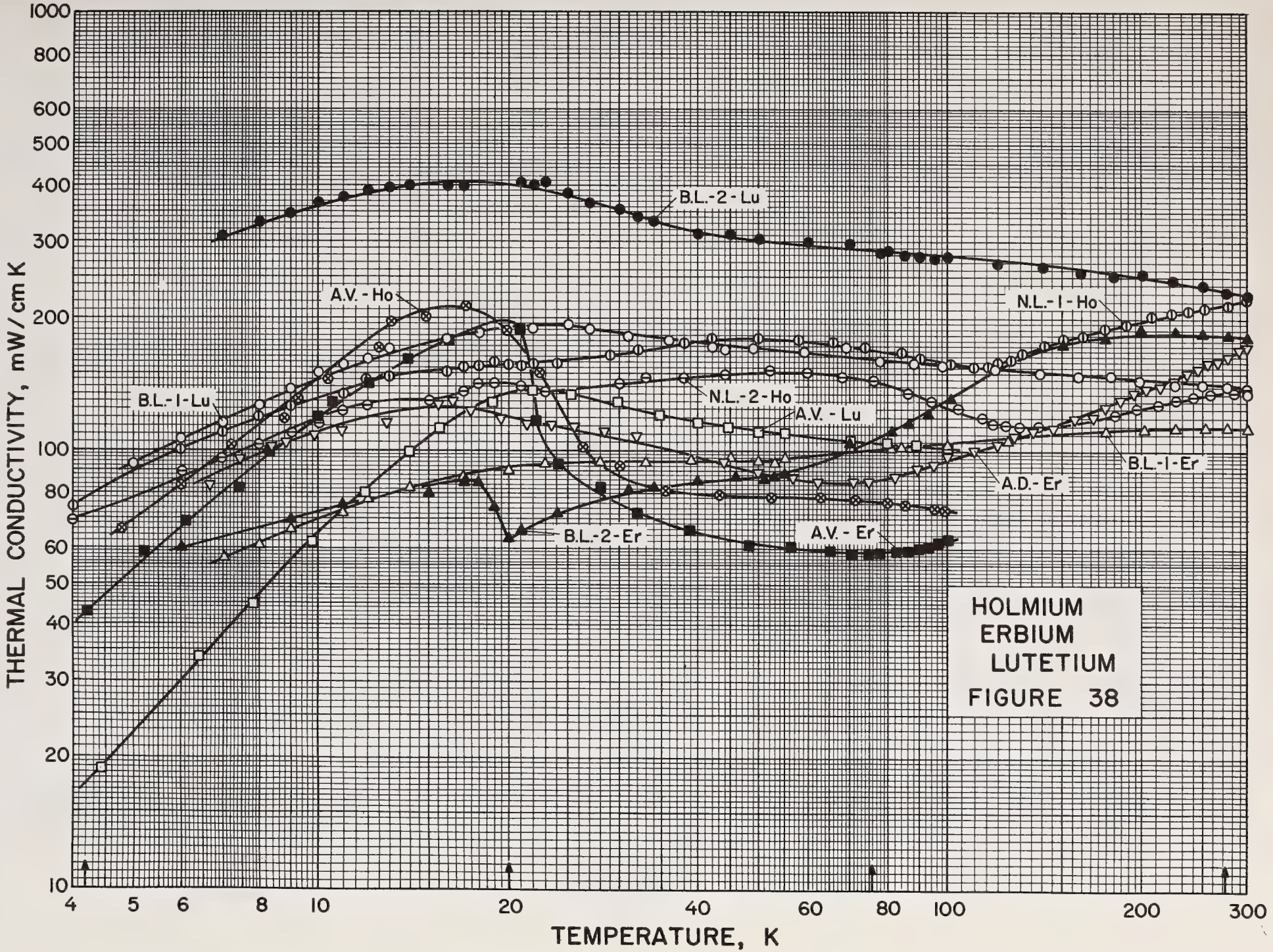
TERBIUM
(See FIGURES 36b and 37)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
A.C.-Tb	Research Chemicals; 0.08% (weight) O_2; 0.06% Y; 0.01% Ca and Si; 0.003% Mg; RRR = 25.	Arc-melted for about 12 minutes; cut and swaged; wrapped in tantalum foil, sealed into a silica capsule evacuated to 10^{-5} mm, annealed for 40 hrs at 790 K; cooled in 3 hrs to room temperature.	A-1; B-1; C-1; D-1(2); E-1; F-4; G-2; L-1; M-1; O-1; R-2; S-1, 5.	S. Arajs and R. V. Colvin (1964).
. . . . .	Johnson, Matthey; < 0.1% other rare-earth metals; ~ 0.02% other base metals.	Reduced in tantalum crucibles from its fluoride; remelted in vacuum. At 291 K, k = 104 mW/cm-K, average value obtained by two-ball and direct reading thermal comparator methods.	A-6; B-1; D-1(2); F-5; G-3; S-1, 5.	B.W. Jolliffe, R.P. Tye, and R.W. Powell (1966); also R.W. Powell and B.W. Jolliffe (1965).
A.V.-1,2-Tb	99.9% pure. #1: RRR(20)= 30. #2: RRR(20)= 15.6.	Annealed in helium atmosphere for $1\frac{1}{2}$ hrs at 650°C.	A-1; B-4; C-1; D-3(2); E-3, 5; G-3; L-1; M-1; S-5.	N.G. Aliev and N. V. Volkenshtein (1966a).
K.R.-1,2-Tb	#1: Johnson, Matthey; RRR(20) = 26.54. #2: Metals Research; RRR(20) = 20.1.	#1: polycrystal. #2: single crystal; grown by the zone melting technique in an argon atmosphere. Rod axis inclined 78° to the c crystal axis. Also measured in an external magnetic field of 0.1 T with no change in values.	A-1; B-1; C-1; D-3(2); E-5; G-3; M-1, 2, 6; N-4; R-2; S-1, 5.	A.G. Karagezyan and K.V. Rao (1969).
N.L.-1,2-Tb	< 200 ppm (weight) Gd and Ta; 160 ppm O_2; < 100 ppm Dy; < 50 ppm Fe; < 20 ppm Ni. #1: RRR(27) = 52.1. #2: RRR(27) = 54.5.	Single crystals; grown by the strain-anneal method; mechanically polished, etched, and electropolished. #1: rod axis parallel to crystal a axis. #2: rod axis parallel to crystal c axis.	A-1; B-2; C-1; D-1(2); E-8; F-4; G-2; L-1, 2; M-1; N-4, 6; S-1, 5.	W.J. Nellis and S. Legvold (1969).
R.S.-Tb	RRR(27) = 20.9.	. . . . .	A-1; B-5; C-1; D-3(2); E-5; F-4; G-2; M-2, 3; Q-1.	R. Ratnalingam and J.B. Sousa (1971).

DYSPROSIUM

(See FIGURES 36a and 36b)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
C.A.-Dy	St. Eloi Corp.; 0.2% (weight) Ta; 0.1% Tb; 0.05% Ca and Ho; 0.02% Er, Si, and Y; 0.01% Fe and Mg; trace of Cu and La; RRR = 9.4.	. . . . .	A-1; B-1; C-1; D-1(2); E-1; F-4; G-2; L-1; M-1; O-1; R-2; S-1, 5.	R. V. Colvin and S. Arajs (1964).
. . . . .	Johnson, Matthey; < 0.1% other rare-earth metals; ~ 0.02% other base metals.	Reduced in vacuum in tantalum crucibles from its fluoride; sublimed in vacuum. At 291 K, k = 104 mW/cm-K, average value obtained by two-ball and direct reading thermal comparator methods.	A-6; B-1; D-1(2); F-5; G-3; S-1, 5.	B. W. Jolliffe, R. P. Tye, and R. W. Powell (1966); also R. W. Powell and B. W. Jolliffe (1965).
R.-Dy	Johnson, Matthey; "pure."	. . . . .	A-1; B-1; C-1; D-3(2); E-5; G-3; M-1; R-2.	K. V. Rao (1967).
B.L.-1, 2-Dy	400 ppm (weight) Ta; 157 ppm O_2; 100 ppm Fe. #1: RRR(27) = 24.2. #2: RRR(27) = 13.4.	Single crystals; grown from arc-melted buttons using the strain-anneal method; cut by spark-erosion method. #1: rod axis parallel to crystal a axis. #2: rod axis parallel to crystal c axis.	A-1; B-2; C-1; D-1(9); E-8; F-4; G-2; L-1, 9; M-1; N-4; R-2; S-1, 5.	D. W. Boys and S. Legvold (1968).
R.S.-1, 2-Dy	#1: RRR(27) = 31.3. #2: RRR(27) = 24.2.	#1: bi-crystal rod. #2: wire. Also measured effect of annealing on #2.	A-1; B-1, 5; C-1; D-3(2); E-5; F-4; G-2; M-2, 3; Q-1.	R. Ratnalingam and J. B. Sousa (1971).


THERMAL CONDUCTIVITY, mW/cm K
TEMPERATURE, K
1000
800
600
500
400
300
200
100
80
60
50
40
30
20
10
4
5
6
8
10
20
40
60
80
100
200
300
B.L.-2-Lu
A.V.-Ho
N.L.-1-Ho
B.L.-1-Lu
N.L.-2-Ho
A.V.-Lu
B.L.-1-Er
A.D.-Er
B.L.-2-Er
A.V.-Er
HOLMIUM
ERBIUM
LUTETIUM
FIGURE 38

HOLMIUM

(See FIGURES 36b and 38)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	Johnson, Matthey; < 0.1% other rare-earth metals; ~ 0.02% other base metals.	Reduced in tantalum crucibles from its fluoride; sublimed in vacuum. At 291 K, k = 106 mW/cm-K, average value obtained by two-ball and direct reading thermal comparator methods.	A-6; B-1; D-1(2); F-5; G-3; S-1, 5.	B.W. Jolliffe, R.P. Tye, and R.W. Powell (1966); also R.W. Powell and B.W. Jolliffe (1965).
A.V.-Ho	99.9% pure; RRR(20) = 10.9.	Annealed in 10^{-6} mm vacuum for 3 hrs at 700°C, wrapped in tantalum foil and placed in a tantalum cylinder.	A-1; B-4; C-1; D-3(2); E-3, 5; G-3; O-1; R-2; S-1, 5.	N.G. Aliev and N. V. Volkenshtein (1966b).
N.L.-1, 2-Ho	< 200 ppm (weight) Dy; < 60 ppm Ni; 48 ppm O_2; < 40 ppm Fe. #1: RRR(27) = 37.8. #2: RRR (27) = 18.9.	Single crystals; grown by the strain-anneal method; mechanically polished, etched, and electropolished. #1: rod axis parallel to crystal a axis. #2: rod axis parallel to crystal c axis.	A-1; B-2; C-1; D-1(2); E-8; F-4; G-2; L-1, 2, 9; M-1; N-4, 6; S-1, 5.	W.J. Nellis and S. Legvold (1969).
See FIGURE 74	. . . . .	Measured below 1 K.	. . . . .	A.C. Anderson and M.E. Malinowski (1970).
R.-Ho	Metals Research Ltd; RRR(20) = 16.6.	Single crystal; zone refined in argon atmosphere; rod axis almost along c axis. Data agree closely with earlier measurements on polycrystalline specimen below 2 K. Trend below 1.25 K unconfirmed.	A-1; B-1; C-1; D-1; E-5; G-3; M-1; N-6; S-5.	K.V. Rao (1969).
R.S.-1, 2-Ho	#1: RRR(27) = 7.23. #2: RRR (27) = 9.95.	. . . . .	A-1; B-1; C-1; D-3(2); E-5; G-2.	R. Ratnalingam and J.B. Sousa (1969 b).
R.S.(1)-1, 2-Ho	#1: RRR(27) = 10.6. #2: RRR(27) = 7.2.	#1: wire. #2: single crystal rod.	A-1; B-1, 5; C-1; D-3(2); E-5; F-4; G-2; M-2, 3; Q-1.	R. Ratnalingam and J.B. Sousa (1971).

ERBIUM

(See FIGURES 36b and 38)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
A.D.-Er	Research Chemicals; before melting, 0.07% (weight) O_2; 0.02% Ho; 0.01% Ca and Si; 0.005% Mg; trace of Tm; RRR = 20.	Arc-melted for 7 min.; machined; swaged; wrapped in tantalum foil, sealed in a silica capsule evacuated to 10^{-5} Torr, annealed for 50 hrs at 800 K; cooled to 300 K in about 10 hrs.	A-1; B-1; C-1; D-1(2); E-1; F-4; G-2; L-1; M-1; O-1; R-2; S-1.	S. Arajs and G.R. Dunmyre (1965).
. . . . .	Johnson, Matthey; < 0.1% other rare-earth metals; ~ 0.02% other base metals.	Reduced in vacuum in tantalum crucibles from its fluoride; sublimed in vacuum. At 291 K, k = 138 mW/cm-K, average value obtained by two-ball and direct reading thermal comparator methods.	A-6; B-1; D-1(2); F-5; G-3; S-1, 5.	B.W. Jolliffe, R.P. Tye, and R.W. Powell (1966); also R.W. Powell and B.W. Jolliffe (1965).
A.V.-Er	99.9% pure; RRR(20) = 10.2.	Annealed in 10^{-6} mm vacuum for 2 hrs at 850°C, wrapped in tantalum foil and placed in tantalum cylinder.	A-1; B-4; C-1; D-3(2); E-3, 5; G-3; O-1; R-2; S-1, 5.	N.G. Aliev and N. V. Volkenshtein (1966b).
B.L.-1, 2-Er	#1: 500 ppm (weight) Ta; 235 ppm O_2; 150 ppm Fe; RRR (27) = 17.4. #2: 900 ppm Fe; <500 ppm Ta; 280 ppm O_2; RRR(27) = 10.1.	Single crystals; grown from arc-melted buttons using the strain anneal method; cut by the spark-erosion method. #1: rod axis parallel to crystal b axis. #2: rod axis parallel to crystal c axis.	A-1; B-2; C-1; D-1; E-8; F-4; G-2; L-1, 9; M-1; N-4; R-2; S-1, 5.	D.W. Boys and S. Legvold (1968).
. . . . .	. . . . .	Measured the change in thermal resistivity of erbium specimens in a magnetic field of up to 2.2T in the temperature range 16-35 K.	. . . . .	G.S. Nikol'skii, N.M. Zvyagina, and V.V. Eremenko (1970).
R.S.-1, 2-Er	#1: RRR(27) = 10.7. #2: RRR(27) = 25.1	#1: thin slab. #2: wire.	A-1; B-4, 5; C-1; D-3(2); E-5; F-4; G-2; M-2, 3; Q-1.	R. Ratnalingam and J.B. Sousa (1971).

THULIUM

(See FIGURES 36b and 37)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	Johnson, Matthey; < 0.1% other rare-earth metals; ~0.01% other base metals.	Reduced in vacuum in tantalum crucibles from its fluoride; sublimed in vacuum. At 291 K, k = 140 mW/cm-K, average value obtained by two-ball and direct reading thermal comparator methods.	A-6; B-4; D-1(2); F-5; G-3; S-1, 5.	B.W. Jolliffe, R.P. Tye, and R.W. Powell (1966); also R.W. Powell and B.W. Jolliffe (1965).
A.V.-Tm	99.99% pure; RRR(20) = 6.2.	Annealed in a stream of helium vapor for 3 hrs at 650°C.	A-1; B-4; C-1; D-3(2); E-3, 5; G-3; R-2; S-5.	N.G. Aliev and N. V. Volkenshtein (1966c).
E.L.-1, 2-Tm	#1: < 300 ppm (weight) Ho; < 200 ppm Lu and Y; 61 ppm O_2; < 50 ppm Fe and Ni; < 30 ppm Er; RRR(27) = 51. #2: < 200 ppm Ho, Lu, and Y; 100 ppm O_2; < 50 ppm Fe and Ni; < 30 ppm Er; RRR(27) = 12.9.	Single crystals; grown by strain-anneal method; annealed in helium atmosphere: 12 hrs at 1200°C in gradient region (25°C/cm), 12 hrs at 1300°C in gradient region, and 16 hrs at 1425 K in constant temperature region; cut by spark-erosion; hand lapped with carborundum paper. #1: rod axis parallel to crystal b axis. #2: rod axis parallel to crystal c axis.	A-1; B-2; C-1; D-1; E-8; F-4; G-3; L-1, 2; M-1; N-4, 6; O-1; R-2; S-1, 2, 5.	L.R. Edwards and S. Legvold (1968).

YTTERBIUM

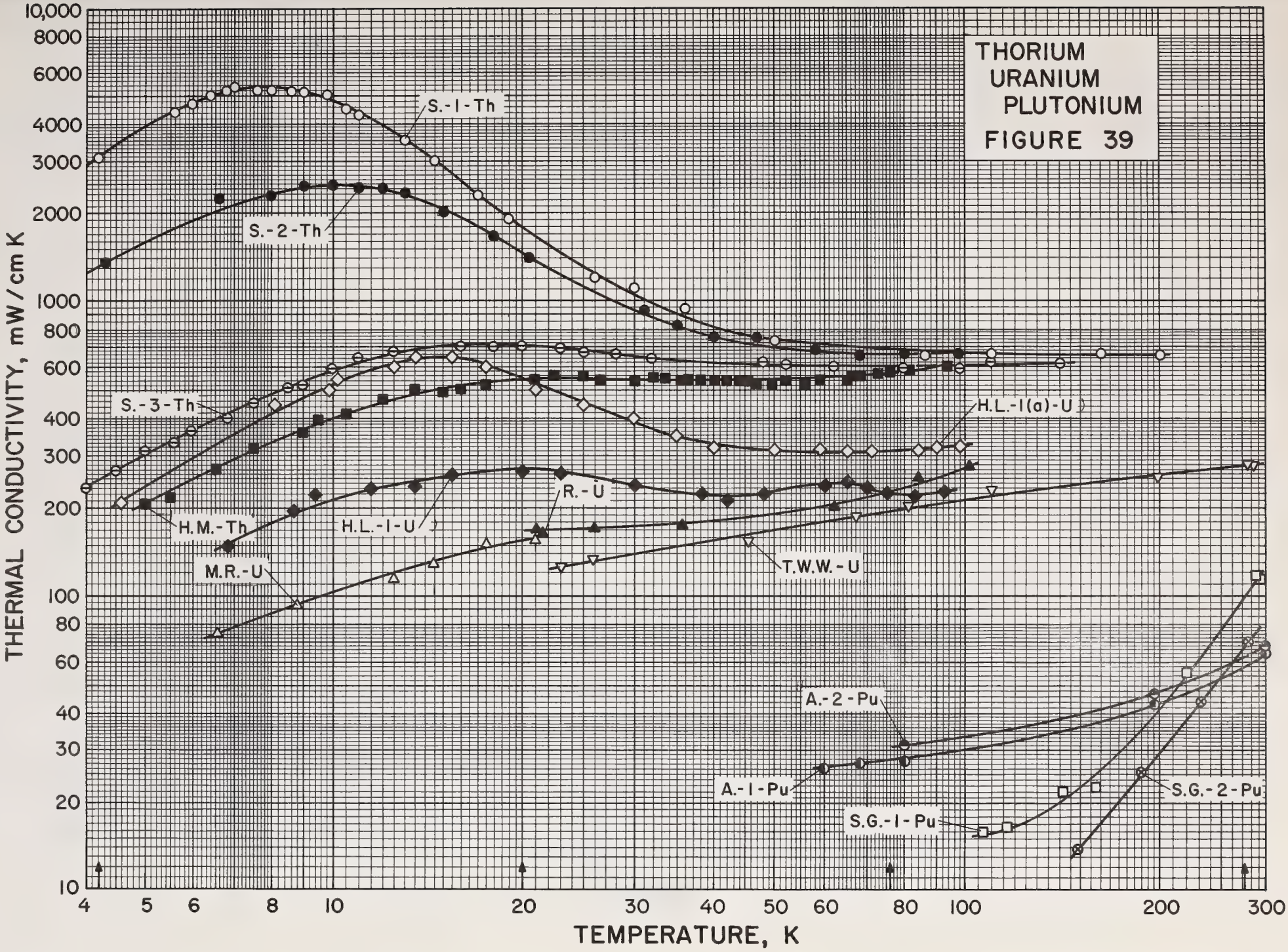
(See FIGURES 36b and 37)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
A.V.-Yb	99.99% pure; RRR(20) = 4.9.	Annealed in a stream of helium vapor for 2.5 hrs at 450°C.	A-1; B-4; C-1; D-3(2); E-3, 5; G-3; R-2; S-5.	N.G. Aliev and N. V. Volkenshtein (1966c).
R.S.-Yb	RRR(27) = 2.23.	. . . . .	A-1; B-5; C-1; D-3(2); E-5; F-4; G-2; M-2, 3; Q-1.	R. Ratnalingam and J. B. Sousa (1971).

LUTETIUM

(See FIGURES 36b and 38)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	Johnson, Matthey; ~0.5% Ta; <0.1% other rare-earth metals; ~0.05% other base metals.	Reduced in vacuum in tantalum crucibles from its fluoride; remelted in vacuum. At 291 K, k = 162 mW/cm-K, average value obtained by two-ball and direct reading thermal comparator methods.	A-6; B-4; D-1(2); F-5; G-3; S-1, 5.	B.W. Jolliffe, R.P. Tye, and R.W. Powell (1966); also R.W. Powell and B.W. Jolliffe (1965).
A.V.-Lu	99.99% pure; RRR(20) = 6.4.	Anneal in a stream of helium vapor for 3 hrs at 600°C.	A-1; B-4; C-1; D-3(2); E-3, 5; G-3; R-2; S-5.	N.G. Aliev and N. V. Volkenshtein (1966c).
B.L.-1,2-Lu	#1: ≤ 200 ppm (weight) Ta; 128 ppm O_2; ≤ 30 ppm Fe; RRR (27) = 28.9. #2: ≤ 200 ppm Ta; 99 ppm O_2; ≤ 30 ppm Fe; RRR(27) = 45.7.	Single crystals; grown from arc-melted buttons using the strain anneal method; cut by spark-erosion method. #1: rod axis parallel to crystal b axis. #2: rod axis parallel to crystal c axis.	A-1; B-2; C-1; D-1; E-8; F-4; G-3; L-1, 9; M-1; N-4; R-2; S-1, 5.	D.W. Boys and S. Legvold (1968).


THORIUM
URANIUM
PLUTONIUM
FIGURE 39
THERMAL CONDUCTIVITY, mW/cm K
TEMPERATURE, K
10,000
8000
6000
4000
3000
2000
1000
800
600
400
300
200
100
80
60
40
30
20
10
4
5
6
8
10
20
30
40
50
60
80
100
200
300
S.-1-Th
S.-2-Th
S.-3-Th
H.M.-Th
H.L.-1(a)-U
H.L.-1-U
R.-U
M.R.-U
T.W.W.-U
A.-2-Pu
A.-1-Pu
S.G.-2-Pu
S.G.-1-Pu

THORIUM

(See FIGURES 36b and 39)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	"A lot of thorium oxide", by x-ray analysis.	k = 290 mW/cm-K at 20°C.	. . . . .	R.W. Powell (1945).
H.M.-Th	"High purity"; probably 10-20 ppm Fe; RRR = 21.	Argon-arc-melted van Arkel metal; machined.	A-1; B-1; C-1; D-4(2); G-3; L-1,2; M-1; O-1; S-1,2,5.	P. Haen and G.T. Meaden (1965).
S.-1,2,3-Th	#1: "from the purest end of the refined rod"; < 5 ppm C; < 3 ppm N_2; RRR = 480. #2: "taken closer to the less pure end"; < 3 ppm N_2; RRR = 140. #3: taken from unpurified Th; 135 ppm O_2; 18 ppm N_2; < 10 ppm C; RRR = 31.	Purified by electrotransport method; annealed under 2×10^{-10} Torr for 100 hrs at 1580°C. Graph of intrinsic thermal resistivity.	A-1; B-1; C-1; D-1(2); G-2; L-1,2; M-1; O-3; Q-1; S-1,5.	H.G. Schettler, J.J. Martin, F.A. Schmidt, and G.C. Danielson (1969).
C.F.-1, 1(s)-Th; also see FIGURE 74	"Nominally pure".	Prepared by the electrotransport method under 10^{-9} Torr. Grain size of 0.01 mm. Measured in both the normal (in magnetic fields up to 0.02 T) and superconducting (s) states. T_c = 1.360 K. Also measured both the normal and superconducting states below 1 K.	A-1; B-1; C-1; D-3(2); E-3,5,6; F-4; G-2; M-1,6; N-3; P-3; Q-1; S-5.	R.L. Cappellett and D.K. Finnemore (1969).

URANIUM

(See FIGURE 39)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	Bureau of Mines (Canada); 260 ppm Si; 188 ppm Fe; 36 ppm Ni; 30 ppm Mn; 10 ppm Cu; 9 ppm Cr; 1 ppm Co; 0.5 ppm Ag.	Refined, and extruded in the γ-phase between 800 and 900°C. #1: heated to 250°C for tinning; k = 234 mW/cm-K at 19.9°C.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-3.	J.D. Babbitt, J.M. Dauphinee, L.D. Armstrong, and W. Peria (1949).
M.R.-U	Atomic Energy Research Establishment.	. . . . .	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1; M-1.	K. Mendelssohn and H.M. Rosenberg (1952b).
T.W.W.-U	. . . . .	Annealed for 10 min at 700°C; quenched in a water bath at 50°C.	A-1; B-1; C-1; D-1(2); E-1; F-2; G-3; L-1; M-1; S-1,2.	W.W. Tyler, A.C. Wilson, Jr., and G.J. Wolga (1952).
R.-U	Same as M.R. above; RRR(20) = 10.6.	. . . . .	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1,2; M-1; S-1, 5.	H.M. Rosenberg (1955).
H.L.-1, 1(a)-U	In ppm(weight): < 150 ppm, < 50, 35 Si, < 20 Zn, < 10 P and Pd, < 5 Sb and V, 2 B, < 2 Aℓ, Cr, Fe, and Mo, 1 Pb, < 1 Ag, Au, Be, Bi, Cu, Ge, In, Mg, Mn, Ni, Sn, and Tℓ.	#1: "as received." #1(a): specimen #1 annealed in vacuum at 900 K for 24 hrs.	A-1; B-1; C-1; D-3(2); G-3; L-1, 3; M-1; N-5; O-1; S-1, 5.	R.O.A. Hall and J.A. Lee (1971).

PLUTONIUM
(See FIGURE 39)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
S.G.-1,2-Pu	#1: 99.95% (weight) Pu; isotopic content: 94.76% (atomic) 239; 4.91% 240; 0.29% 241; 0.04% 242. #2: 99.93% (weight) Pu; isotopic content: 95.33% (atomic) 239; 4.39% 240; 0.28% 241; 0.06% 242.	#1: density of 19.58 g/cm^3. #2: density of 19.53 g/cm^3. Another specimen was also measured with intermediate values.	A-1; B-1; C-1; D-1(4); F-4; G-3; M-1; N-5, 6; S-1, 5.	T.A. Sandenaw and R.B. Gibney (1958).
A.-1,2-Pu	> 99.98% pure α-plutonium.	#1: arc-melted and induction cast into a MgO mold. Density of 19.62 g/cm^3; randomly oriented grains; large number of microcracks. #2: heated the case ingot into β-phase, then cooled to room temperature under a compressive load of 60,000 psi. Density of 19.77 g/cm^3; randomly oriented grains; few microcracks; rod axis perpendicular to the (020) crystal axis. Two other specimens, one chill-cast and annealed and the other with rod axis parallel to the (020) crystal axis, were measured with intermediate values.	A-4; B-1; C-1; D-1(3); F-4; E-1; G-3; M-1; S-1, 5.	J.F. Andrew (1967).

NEPTUNIUM

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	Rolled into foil, mounted on slide. K = 0.077 watts/cm K at 300 K.	A-3; B-4; C-5; D-1; E-7; F-5; G-3; S-5	Wagner (1971)

3.2. ALLOYS AND COMMERCIAL METALS

ALKALI METAL ALLOYS
(See FIGURE 51b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Sodium-potassium; 50-50 by atomic percent.	k = 290 mW/cm-K at -8.9°C; k = 300 mW/cm-K at -10.6°C.	A-4; B-1; C-3; D-1(3); E-7; F-5; G-3; L-1; M-1; S-1.	J.W. Hornbeck (1913).
A.D.J.-1, 2, 3, 4, 5-KCs	#1-4: K supplied by L. Light and Co.; #5: K supplied by A.D. McKay; Cs supplied for all specimens by both companies. Estimated Cs concentration, #2-5: 4.4%, 2.2%, 1.18%, 0.069% (atomic), respectively.	Melted and mixed components under vacuum, cast into nylon tubes, pressurized with atmosphere of helium, repeat cycle several times to remove voids; quench cooled through melting range and annealed at room temperature before measurement; 3 mm bore on nylon tube.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-2; L-1, 2, 4, 6, 9; N-1, 7; P-2, 3, 4; Q-1, 2, 3, 4; R-1, 5.	M.A. Archibald, J. E. Dunick, and M.H. Jericho (1967).

BERYLLIUM ALLOY

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Commercially pure; Beryllium Co. of America.	See FIGURE 4a, under "Metallic Elements."	. . . . .	E.J. Lewis (1929).

MAGNESIUM ALLOYS

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
		Values below are in W/cm-k.		
. . . . .	0.5 Mn.	k = 1.60 at 273 K, 1.34 at 87 K.	A-6; B-1; C-1; D-1(2); E-2; F-4; G-3; S-1, 5.	J. Staebler (1929).
. . . . .	0.8 Mn.	k = 1.58 at 273 K, 1.22 at 87 K.	Same as above.	Same as above.
. . . . .	2 Mn.	k = 1.18 at 273 K, 0.67 at 87 K.	Same as above.	Same as above.
. . . . .	3.54 Mn.	k = 1.02 at 273 K, 0.57 at 87 K.	Same as above.	Same as above.
. . . . .	6 Al.	k = 0.80 at 273 K, 0.59 at 87 K.	Same as above.	Same as above.
. . . . .	8 Al.	k = 0.65 at 273 K, 0.42 at 87 K.	Same as above.	Same as above.
. . . . .	12 Al.	k = 0.59 at 273 K, 0.33 at 87 K.	Same as above.	Same as above.
. . . . .	0.7 Si.	k = 1.48 at 273 K, 1.10 at 87 K.	Same as above.	Same as above.
. . . . .	1.5 Si.	k = 1.40 at 273 K, 0.95 at 87 K.	Same as above.	Same as above.
. . . . .	8 Ce.	k = 1.25 at 273 K, 1.06 at 87 K.	Same as above.	Same as above.
. . . . .	12 Ce.	k = 1.03 at 273 K, 0.81 at 87 K.	Same as above.	Same as above.
. . . . .	8 Cu.	k = 1.25 at 273 K, 0.88 at 87 K.	Same as above.	Same as above.
. . . . .	8 Zn.	k = 1.19 at 273 K, 0.89 at 87 K.	Same as above.	Same as above.
. . . . .	8 Cd.	k = 1.42 at 273 K, 1.30 at 87 K.	Same as above.	Same as above.
. . . . .	2 Si, 6 Al.	k = 0.69 at 273 K, 0.48 at 87 K.	Same as above.	Same as above.
. . . . .	2 Si, 8 Al.	k = 0.61 at 273 K, 0.38 at 87 K.	Same as above.	Same as above.
. . . . .	2 Si, 10 Al.	k = 0.55 at 273 K, 0.29 at 87 K.	Same as above.	Same as above.
. . . . .	2 Si, 12 Al.	k = 0.54 at 273 K, 0.28 at 87 K.	Same as above.	Same as above.
. . . . .	15 Cu.	k = 1.54 at 273 K, 1.41 at 87 K; chill-cast.	A-1; B-1; C-1; D-1(2); E-2; F-4; G-3; S-1, 5.	W. Mannchen (1931).
. . . . .	20 Cu, 3 Si.	k = 1.08 at 273 K, 0.89 at 87 K; chill-cast.	Same as above	Same as above.
. . . . .	2.2 Ag.	k = 1.31 at 27°C; all below are vacuum-annealed.	A-4; B-1; C-3; D-1(2); E-1; F-4; G-3; S-1, 5.	R. Kikuchi (1932).
. . . . .	6.0 Ag.	k = 1.16 at 27°C.	Same as above.	Same as above.
. . . . .	2.1 Al.	k = 0.88 at 27°C.	Same as above.	Same as above.
. . . . .	4.2 Al.	k = 0.69 at 22°C.	Same as above.	Same as above.
. . . . .	6.2 Al.	k = 0.56 at 22°C.	Same as above.	Same as above.
. . . . .	8.2 Al.	k = 0.51 at 18°C.	Same as above.	Same as above.
. . . . .	10.3 Al.	k = 0.45 at 19°C.	Same as above.	Same as above.
. . . . .	12.2 Al.	k = 0.39 at 23°C.	Same as above.	Same as above.
. . . . .	2.4 Cu.	k = 1.39 at 20°C.	Same as above.	Same as above.
. . . . .	6.3 Cu.	k = 1.31 at 24°C.	Same as above.	Same as above.
. . . . .	1.9 Ni.	k = 1.36 at 20°C.	Same as above.	Same as above.
. . . . .	5.8 Ni.	k = 1.26 at 24°C.	Same as above.	Same as above.

MAGNESIUM ALLOYS (cont'd)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	2.2 Sn.	k = 1.06 at 21°C.	A-4; B-1; C-1; D-1(2); E-1; F-4; G-3; S-1, 5.	R. Kikuchi (1932).
. . . . .	6.4 Sn.	k = 0.74 at 22°C.	Same as above.	Same as above.
. . . . .	2.1 Zn.	k = 1.26 at 26°C.	Same as above.	Same as above.
. . . . .	6.1 Zn.	k = 1.09 at 26°C.	Same as above.	Same as above.
. . . . .	4 Zn, 0.5 Cu.	"Elektron" k = 1.14 at 26°C.	Same as above.	Same as above.
. . . . .	4 Al, 1 Zn, 1 Cd, 1 Sn.	k = 0.56 at 22°C.	Same as above.	Same as above.
. . . . .	6 Al, 3 Zn, 0.4 Cu.	"Dow metal", k = 0.61 at 29°C.	Same as above.	Same as above.
. . . . .	4 Al, 0.5 Zn, 2 Cd, 1 Sn.	k = 0.63 at 22°C.	Same as above.	Same as above.
. . . . .	4 Al, 3 Cd, 1 Sn.	k = 0.69 at 22°C.	Same as above.	Same as above.
. . . . .	4 Al, 2 Cd, 2 Sn.	k = 0.56 at 30°C.	Same as above.	Same as above.
		All values listed below are near room temperature.		
. . . . .	8 Al, 0.2 Mn.	ASTM A8; ASTM AM80A; Dowmetal A; Mazlo AM 241; British DTD 59A, DTD 289, Elektron A8, Elektron A8K; k = 0.75.	. . . . .	Alloy Digest (1952-68).
. . . . .	10 Al, 0.1 Mn.	ASTM A10; ASTM 100A; Dowmetal G; Mazlo AM 240; AM-C59S; British DTD 259; Elektron VI; k = 0.71.	. . . . .	Same as above.
. . . . .	1.0-1.5 Al, 0.5-1.5 Mn, 0.3 Si, 0.05 Cu, 0.005 Fe and Ni.	Eclipsaloy 130; k = 0.71.	. . . . .	Same as above.
. . . . .	3 Al, 1 Zn, 0.3 Mn.	ASTM AZ 31X, A, B; Dowmetal FS-1; Mazlo AM-C52S; Whitelight FS-1; British DTD 120A; Elektron AZ 31; k = 0.96.	. . . . .	Same as above.
. . . . .	5 Al, 1 Zn, 0.25 Mn.	ASTM AZ51 X; Dowmetal JS-1; k = 0.88.	. . . . .	Same as above.
. . . . .	6 Al, 1 Zn, 0.2 Mn.	ASTM AZ 61 X, A, B; Dowmetal J-1; Mazlo AM-C57S; Whitelight J-1; British DTD 88B; DTD 120A, DTD 259; Elektron AZM; k = 0.80.	. . . . .	Same as above.
. . . . .	6 Al, 3 Zn, 0.2 Mn.	ASTM 63, A; Dowmetal H; Mazlo AM 265; British DTD 59A, DTD 289; Elektron AZG; k = 0.75.	. . . . .	Same as above.
. . . . .	7.5 Al, 0.7 Zn, 0.15 Mn.	ASTM AZ81A(T4); k = 0.50.	. . . . .	Same as above.
. . . . .	8.5 Al, 0.5 Zn, 0.15 Mn.	ASTM AZ80X, A; Dowmetal O-1; Mazlo AM-C58S; Whitelight O-1; British DTD 88B; Elektron AZ 855; k = 0.75.	. . . . .	Same as above.

MAGNESIUM ALLOYS (cont'd)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	9 Aℓ; 0.7 Zn, 0.2 Mn.	ASTM AZ91A, B, C; Dowmetal R, RC; Mazlo AM 263; British DTD 136 A; Elektron AZ 91; k = 0.71.	. . . . .	Alloy Digest (1952-68).
. . . . .	9 Aℓ; 2 Zn, 0.1 Mn.	ASTM AZ92, A; Dowmetal C; Mazlo AM 260; k = 0.71.	. . . . .	Same as above.
. . . . .	4 Aℓ, 0.2 Mn.	Mazlo AM 244; k = 0.96.	. . . . .	Same as above.
. . . . .	1.5 Mn.	ASTM M1A, B; Dowmetal M; Mazlo AM 403, AM 35; Whitelight M; British DTD 142, 118, 140 A; Elektron AM 503; k = 1.26.	. . . . .	Same as above.
. . . . .	0.8-2.0 Th, 1.0 Mn.	ASTM HM11XA; k = 1.0.	. . . . .	Same as above.
. . . . .	2 Th, 0.5 Mn.	ASTM HM21A; k = 1.38.	. . . . .	Same as above.
. . . . .	3 Th, 1.2 Mn.	ASTM HM31A; k = 1.04.	. . . . .	Same as above.
. . . . .	3.25 Th, 0.7 Zr.	ASTM HK31A; Dowmetal HK31XA; k = 0.92.	. . . . .	Same as above.
. . . . .	3.25 Th, 2 Zn, 0.75 Zr.	ASTM HZ32A; Dowmetal HZ32XA; Elektron ZT1; k = 1.09.	. . . . .	Same as above.
. . . . .	2.0-2.6 Zn, 0.45 Zr.	ASTM ZK21A; k = 1.27.	. . . . .	Same as above.
. . . . .	2.5-4.0 Zn, 0.5-1.0 Zr, 0.15 Mn, 0.03 Cu, 0.02 Aℓ, 0.01 Fe and Si, 0.005 Ni.	Elektron ZW3; k = 1.25.	. . . . .	Same as above.
. . . . .	4 Zn, 2 Th, 0.5 Zr.	ASTM ZH42; k = 1.13.	. . . . .	Same as above.
. . . . .	4.25 Zn, 1.25 Rare Earths, 0.50 Zr.	ASTM ZE41A; British RZ5; k = 1.13.	. . . . .	Same as above.
. . . . .	4.5 Zn, 0.7 Zr.	ASTM ZK41A; Elektron Z5Z; k = 1.11.	. . . . .	Same as above.
. . . . .	5.7 Zn, 1.8 Th, 0.7 Zr.	ASTM ZH62A; Elektron TZ6; k = 1.11.	. . . . .	Same as above.
. . . . .	3.0 Rare Earths, 0.2 Zr.	ASTM EK30A; k = 1.11.	. . . . .	Same as above.
. . . . .	3 Rare Earths, 0.35 Zr, 0.3 Zn.	Dowmetal EK30A; k = 1.13.	. . . . .	Same as above.
. . . . .	3.0 Rare Earths, 2.7 Zn, 0.5 Zr.	Dowmetal EZ33A; Elektron ZRE1; k = 1.0.	. . . . .	Same as above.
. . . . .	4.0 Rare Earths, 0.6 Zr.	Dowmetal EK41A; k = 1.0.	. . . . .	Same as above.
. . . . .	2.5-4.0 Rare Earths, 2.0-3.5 Zn, 0.55-0.85 Zr, 0.15 Mn, 0.05 Si, 0.05 Cu.	Flylite ZRE-1; k = 1.0.	. . . . .	Same as above.
. . . . .	2.5-4.0 Rare Earths, 0.4-1.0 Zr, 0.20 Zn, 0.15 Mn, 0.03 Cu, 0.01 Fe and Si, 0.005 Ni.	Elektron MCZ; k = 1.0.	. . . . .	Same as above.
. . . . .	2.5-4.0 Rare Earths, 0.4-1.0 Zr, 0.3-0.7 Zn, 0.15 Mn, 0.03 Cu, 0.01 Fe and Si, 0.005 Ni.	Elektron ZERO; k = 1.0.	. . . . .	Same as above.

MAGNESIUM ALLOYS (cont'd)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	3.0-5.0 Rare Earths, 0.3 Zr, 0.1 Mn and Si, 0.05 Aℓ and Cu, 0.01 Fe.	Eclipsaloy 517; k = 1.05.	. . . . .	Alloy Digest (1952-68).
. . . . .	2.0-3.0 Ag, 1.2-2.0 Rare Earths, 0.4-1.0 Zr.	ASTM MSR-A; British DTD 5025; k = 1.13.	. . . . .	Same as above.

TITANIUM ALLOYS
(See FIGURE 51a)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	2.8 Cr, 1 Fe.	Abstract only; k = 130 mW/cm-K at 273 K; k = 100 mW/cm-K at 195 K; k = 60 mW/cm-K at 80 K.	. . . . .	C. I. Rigney and L. I. Bockstahler (1951).
T. W. -Ti.	Rem-Cru Titanium, RC-130-B; 4.7 Mn, 3.99 Al, 0.14 C.	. . . . .	A-1; B-1; C-1; D-1(2); E-1; F-2; G-3; S-1, 2, 5.	W. W. Tyler and A. C. Wilson (1952).
Z. M. W. - 2.5 Al-16V, 6 Al-4V	Mallory-Sharon Metals Corporation. 2.5 Al-16V: 14.95 (weight) V, 2.75 Al, 0.21 Fe, 0.03 C, 0.015 N_2, 66 ppm H_2. 6 Al-4V: 5.89 (weight) Al, 3.87 V, 0.15 Fe, 0.02 C, 0.015 N_2, 50 ppm H_2.	2.5 Al-16V: solution heat treated at 766°C for 30 min, then aged at 532°C for 4 hrs. 6Al-4V: solution heat-treated at 927°C for 20 min, oil-quenched, aged at 482°C for 4 hrs and air-cooled. Two other specimens also measured: 4Al-3Mo-1V, 10% greater than 6Al-4V at 300 K; 13 V-11Cr-3Al, 10% less than 2.5 Al-16V at 300 K.	A-1; B-4; C-1; D-1(3); E-2; F-2; G-3; L-1; M-1.	W. T. Ziegler, J. C. Mullins, and S. C. P. Hwa (1963).
G. -1, 2, 3-Ti Ni.	Ni: Mond; >99.9% pure. Ti: Du Pont (lot # KZ-3404); high purity. #1: no solute; RRR(27) = 3.2. #2: 1.7 (atomic) Cu solute; RRR(27) = 2.0. #3: 8.1 (atomic) Cu solute; RRR(27) = 0.67.	Ti Ni specimens; prepared from nickel shot and titanium sponge; rods were hot swaged, furnace cooled from homogenized buttons, machined. Grain size of: 42, 46, and 54μ, respectively. Another specimen, with 18.3% (atomic) Ni solute, was also measured, with values <10% greater than #1. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-1(2); E-3; F-4; G-2; M-1; N-5, 7; O-3, 5; S-1, 2, 5.	J. F. Goff (1964).
. . . . .	Nb + 67 Ti.	See D. S. -1(s)-Nb+67Ti on NIOBIUM ALLOYS Table and Figure.	. . . . .	L. Dubeck and K. S. L. Seatty (1968).
H. P. -Ti A-110AT	5.5 (weight) Al, 2.5 Sn, 0.2 Fe, <0.1 C, N_2, and H_2, balance Ti; RRR(17) = 1.06.	Ti A-110 AT; annealed; hcp structure; Rockwell hardness of C-35; average grain size of 0.015 mm.	A-1; B-1; C-1; D-1(8); E-1, 2, 3; F-1; G-1; L-1; M-1; N-1, 6; O-1, 3; P-2, 4, 6; S-1, 2, 5.	J. G. Hust and R. L. Powell (1969).

ZIRCONIUM ALLOYS

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	2 Hf, 0.2 Cr + Fe, 0.05 C, 0.01 N_2.	Zirconium Gr. 11; k = 209 mW/cm-K at room temperature.	. . . . .	Alloy Digest (1952-68).
. . . . .	1.25-1.65 Sn, 0.07-0.17 Fe, 0.06-0.14 Cr, 0.03-0.07 Ni, 100 ppm Hf.	Jessop-Saville Zirconium Alloy; Zircaloy 2; k = 167 mW/cm-K at room temperature.	. . . . .	Same as above.

HAFNIUM ALLOY

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Wah Chang; 21.8(weight) Ta; 2.2 Mo, ~2.0 Zr, <0.03 Nb, <0.01 Fe, <300 ppm O_2, <100 ppm N_2, <50 ppm C, <25 ppm H_2.	Arc-cast; forged at 2100°F. Calculated from thermal diffusivity measurements; k = 155 mW/cm-K at 25°C. Density of 13.41 g/cm^3.	. . . . .	G. L. Denman (1969).

NIOBIUM ALLOYS
(See FIGURES 51a-51b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
R. N. -1, 1(s)-Nb+0.2Zr;2, 2(s)-Nb+2Zr.	#1: 0.2 (atomic) Zr. #2: 2 (atomic) Zr.	Measured in both the normal (in magnetic fields of 1.0 T or larger) and superconducting (s) states. #2: $T_c = 8.46$K. Graph of the ratio of the electronic contribution of the superconducting to normal states as a function of reduced temperature; graph of the phonon mean-free-path as a function of reduced temperature.	A-1; B-5; C-1; D-3(2); F-4; G-3; M-2; N-3; O-5; P-3; Q-1.	R. Radhakrishna and M. Nielsen (1963).
C. C. -1, 1(s)-Nb_3Sn.	Nb_3Sn.	Obtained by vapor deposition. Measured in both the normal (in magnetic fields up to 0.65 T) and superconducting (s) states. $T_c = 18.3$K. Consisted of oriented platelets 1μ and 10μ in diameter and 200-2000 Å in thickness. Graph of thermal conductivity as a function of inverse reduced temperature; graph of phonon contribution to thermal conductivity as a function of T^3.	A-1; B-4; C-1; D-3(2); E-4, 5; G-2; M-1, 4; N-3; O-5; P-5.	G. D. Cody and R. W. Cohen (1964).
D. S. -1(s)-Nb+67Ti.	67 (atomic) Ti.	Prepared by vacuum arc melting, forged, cold rolled; heavily-worked defect-loaded material. Measured in the superconducting (s) state. Measured in longitudinal magnetic fields of 0-0.6 T. $T_c = 9.7$K.	A-1; B-1; C-1; D-3(2); E-5; G-3; N-3; P-1, 3.	L. Dubeck and K. S. L. Setty (1968).
. . . . .	64 Nb, 36 Ta.	See G. L. Denman (1969) under TANTALUM ALLOYS Table for specimen of 36 Ta-64 Nb.	. . . . .	G. L. Denman (1969).

TANTALUM ALLOYS
(See FIGURE 51b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
R-1, 1(s), 2, 2(s), 3, 3(s)-Ta Nb.	Services Electronic Research Laboratory. #1: 92Ta-8Nb. #2: 71Ta-29Nb. #3: 53Ta-47Nb.	Mixed single crystals. #1: $T_c = 4.8$ K. #2: $T_c = 5.4$ K. #3: $T_c = 6.2$. Measured in both the normal (in transverse fields up to 0.6 T) and superconducting (s) states. Graph of the ratio of the superconducting to normal state conductivity as a function of reduced temperature. A specimen of 36Ta-64Nb had normal state measurements approximately the same as 53Ta-47Nb, but were significantly higher in the superconducting state.	G-2; M-1; N-3; O-1; P-1; Q-1.	A. F. Rice (1962).
L-1(s), 2, 2(s)-Ta Nb.	Grown at Services Electronic Research Laboratory from Johnson, Matthey stock; spectroscopically standardized materials. #1: ~5% (atomic) Nb; RRR(27) = 13.5. #2: ~20% (atomic) Nb; RRR(27) = 6.6.	Single crystals; grown by electron bombardment floating zone technique. #1: $T_c = 4.55$ K; #2: $T_c = 4.64$ K. Measured in both the normal (in a field of ~0.45 T) and superconducting (s) states.	G-3; M-1; N-3; Q-1.	J. Lowell (1966).
. . . . .	#1: Fansteel Met.; 9.11(weight) W, 0.02 Nb, 0.01 Fe and Zr, 0.002 Cr, 20 ppm O_2, 19 ppm C. #2: Westinghouse; 7.87 (weight) W, 2.00 Hf, 0.3 Nb, 0.08 Fe, 0.06 Zr, 0.003 Cr, 34 ppm O_2, 23 ppm N_2, 18 ppm C, 3.8 ppm H_2. #3: Westinghouse; 8.86(weight) W, 2.45 Hf, 0.07 Zr, 0.04 Nb, 0.007 Fe, 0.002 Cr, 90 ppm C, 12.1 ppm H_2, 6 ppm O_2.	Values calculated from thermal diffusivity measurements. #1: Ta-10W; arc-cast and fully annealed; k = 480 mW/cm-K at 27°C; density of 16.82 g/cm^3. #2: Ta-8W-Z Hf; double arc cast, extruded at 3000°F, forged at 2200°F, annealed 1 hr at 1050°C; k = 370 mW/cm-K at 27°C; density of 16.79 g/cm^3. #3: Ta-10W-2.5 Hf - 0.01 C; double arc cast, extruded at 2400°F, forged at 2200°F; k = 360 mW/cm-K at 27°C; density of 13.41 g/cm^3.	. . . . .	G. L. Denman (1969).

CHROMIUM ALLOYS

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	41.3 (weight) Fe, 4.45 C, 0.45 Si.	Ferrochromium; k = 520 mW/cm-K at 26°C.	A-4; B-4; C-1, 2; D-1(2), F-4; G-3; M-2.	N. N. Kurnakov and S. D. Rakhmanovski (1937).
. . . . .	53.73 Cr, 1.12 Si, 0.24 C, balance Fe.	Ferrochromium; k = 570 mW/cm-K at 20°C.	Same as above.	Same as above.

MOLYBDENUM ALLOYS

(See FIGURE 51b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
L. D.-1(s)-MoRe	Chase Brass and Copper Co.; 47.98 (weight) Re, 70 ppm Fe, 40 ppm O_2, 30 ppm C, 10 ppm N_2, 6 ppm Si, 5 ppm Al and H_2, 4 ppm Mn and Ni, 3 ppm Co and Cr, 2 ppm Cu, K, Na, Sn, Ti, and Zr, 1 ppm B, Ca, and Mg.	90% cold worked, annealed for 19 hrs at 1250°C, cooled slowly, identically annealed again, water quenched, low-temperature thermally cycled and identically annealed twice. In bcc structure with 28% complex tetragonal structure phase. Measured in superconducting (s) phase. Also measured another specimen (with composition 59.5-60.5% Mo and 39.5% Re) with identical results. Measurements of normal state (in external magnetic field of 3T) had identical values between 2 and 5 K (see Daunt reference). Graphs of thermal conductivities of specimens in various anneal states in temperature range of 2.45-4.49 K versus magnetic fields up to 4.5 T.	A-1; B-5; C-1; D-2(2); E-5; F-4; G-3; M-1; N-2, 3; P-1, 2, 3, 4, 6; Q-1; S-1.	E. Lerner and J. G. Daunt (1966); see also J. G. Daunt (1964).
. . . . .	0.40-0.55 Ti, 0.01-0.04 C.	Molybdenum, 0.5% Ti; Climelt, molybdenum -0.5% Ti; k = 1180 mW/cm-K at room temperature.	. . . . .	Alloy Digest (1952-68).
. . . . .	0.40-0.55 Ti, 0.06-0.12 Zr, 0.01-0.04 C.	Climelt, molybdenum, 0.5% Ti-0.08% Zr; Fansteel 42; k = 1400 mW/cm-K at room temperature.	. . . . .	Same as above.
. . . . .	0.40-0.55 Ti, 0.06-0.12 Zr, 0.01-0.04 C, 0.0025 O_2, 0.002 N_2, 0.0005 H_2.	TZM; k = 1310 mW/cm-K at room temperature.	. . . . .	Same as above.

TUNGSTEN ALLOYS
(See FIGURE 51a)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	"Impure"; RRR = 20.	Single crystal; k = 1830 mW/cm-K at 83 K; k = 1800 mW/cm-K at 21 K.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-3; L-1, 2; P-1; S-1, 5.	E. Gruneisen and E. Goens (1927).
M. McE. B. - W+2 Ta	2 Ta; RRR = 4.1.	Density of 19.19 g/cm^3.	A-1; B-1; C-1; D-1(2); E-1; F-1; G-1; L-1, 2; S-1, 2, 5.	J. P. Moore, D. L. McElroy, and M. Barisoni (1966).
. . . . .	5(Ni + Cu).	Mallory 2000; k = 1370 mW/cm-K at room temperature.	. . . . .	Alloy Digest (1952-68).
. . . . .	6 Ni, 4 Cu.	Mallory 1000; k = 1380 mW/cm-K at 18°C.	. . . . .	Same as above.
. . . . .	10(Ni + Fe).	Mallory 3000; k = 760 mW/cm-K at room temperature.	. . . . .	Same as above.
. . . . .	10(Cu + Ni + Mo + Fe).	Gyromet; k = 980 mW/cm-K at room temperature.	. . . . .	Same as above.

MANGANESE ALLOYS

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	79.0 Mn, 2.36 C, 1.75 Si, balance Fe.	Ferromanganese; k = 490 mW/cm-K at 15.0°C.	A-4; B-4; C-1, 2; D-1(2); F-4; G-3; M-2.	N. N. Kurnakov and S. D. Rakhmanovski (1937).
. . . . .	78.18 Mn, 2.98 Si, 1.38 C, balance Fe.	Ferromanganese; k = 490 mW/cm-K at 14.5°C.	Same as above.	Same as above.
. . . . .	73.02 Mn, 6.62 C, 1.69 Si, balance Fe.	Ferromanganese; k = 460 mW/cm-K at 15.3°C.	Same as above.	Same as above.
. . . . .	18-22 Cu.	C. D. C. Manganese Alloy No. 780; k = 84 mW/cm-K at room temperature.	. . . . .	Alloy Digest (1952-68).
. . . . .	17.9-18.1 Cu, 9.9-10.1 Ni.	C. D. C. Manganese Alloy No. 772; k = 84 mW/cm-K at room temperature.	. . . . .	Same as above.

Due to the overlapping of the composition of classifications of steels, a set of limits has been set by the authors. In some cases the alloy composition could be on the border between two classifications, in which case the alloy will be listed in both groups. Following are the classifications with the composition limits:

Carbon steel

0.1 - 2% C

<0.5% Si

0.5 - 2% Mn

<1% other metals

Alloy steel

0.1 - 1% C

0.1 - 2% Si

1 - 25% Mn or Ni

<5% total Cr, Mo, V

Iron alloys

>25% Co, Mn, or Ni

Cast iron

2 - 4% C

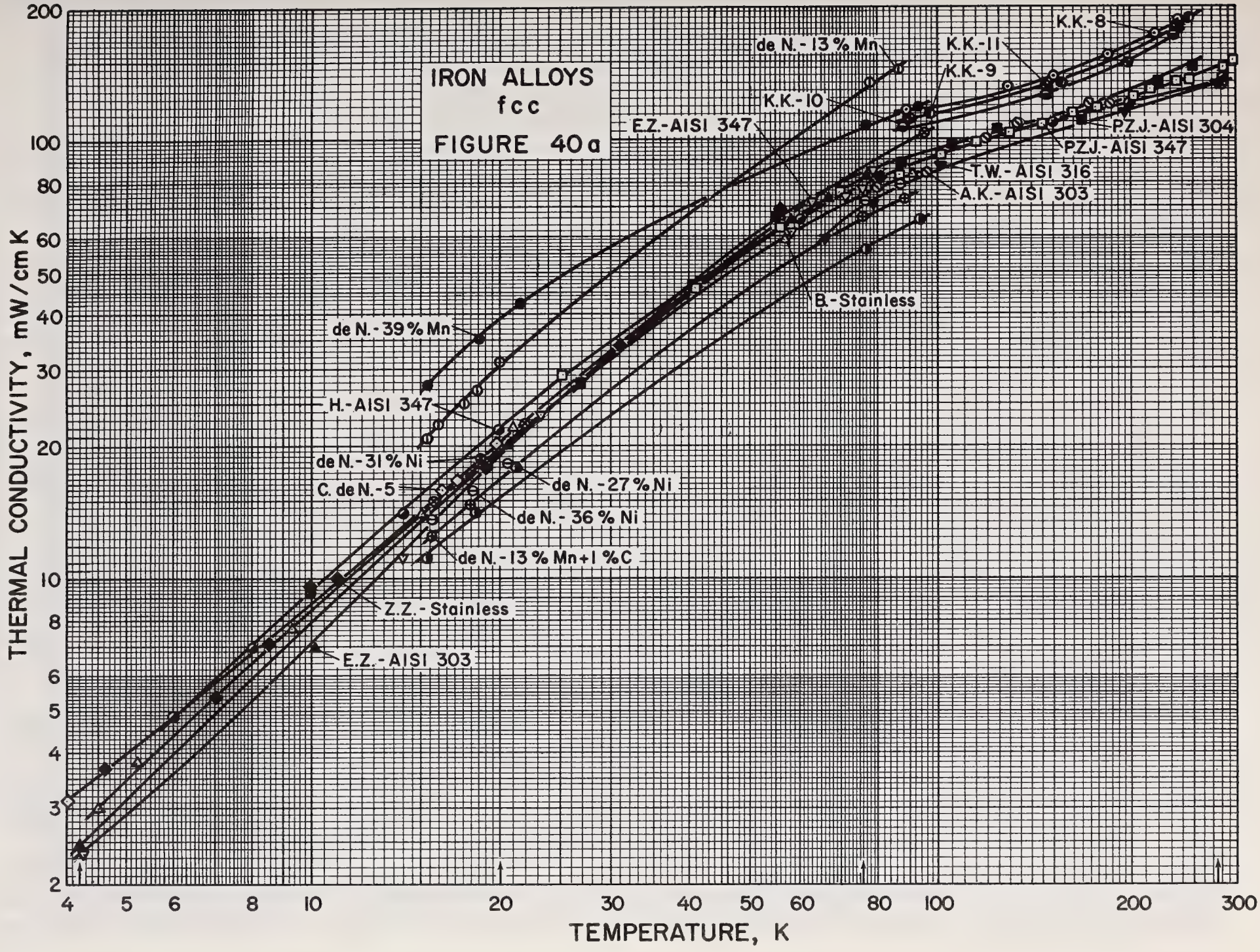
1 - 5% Si

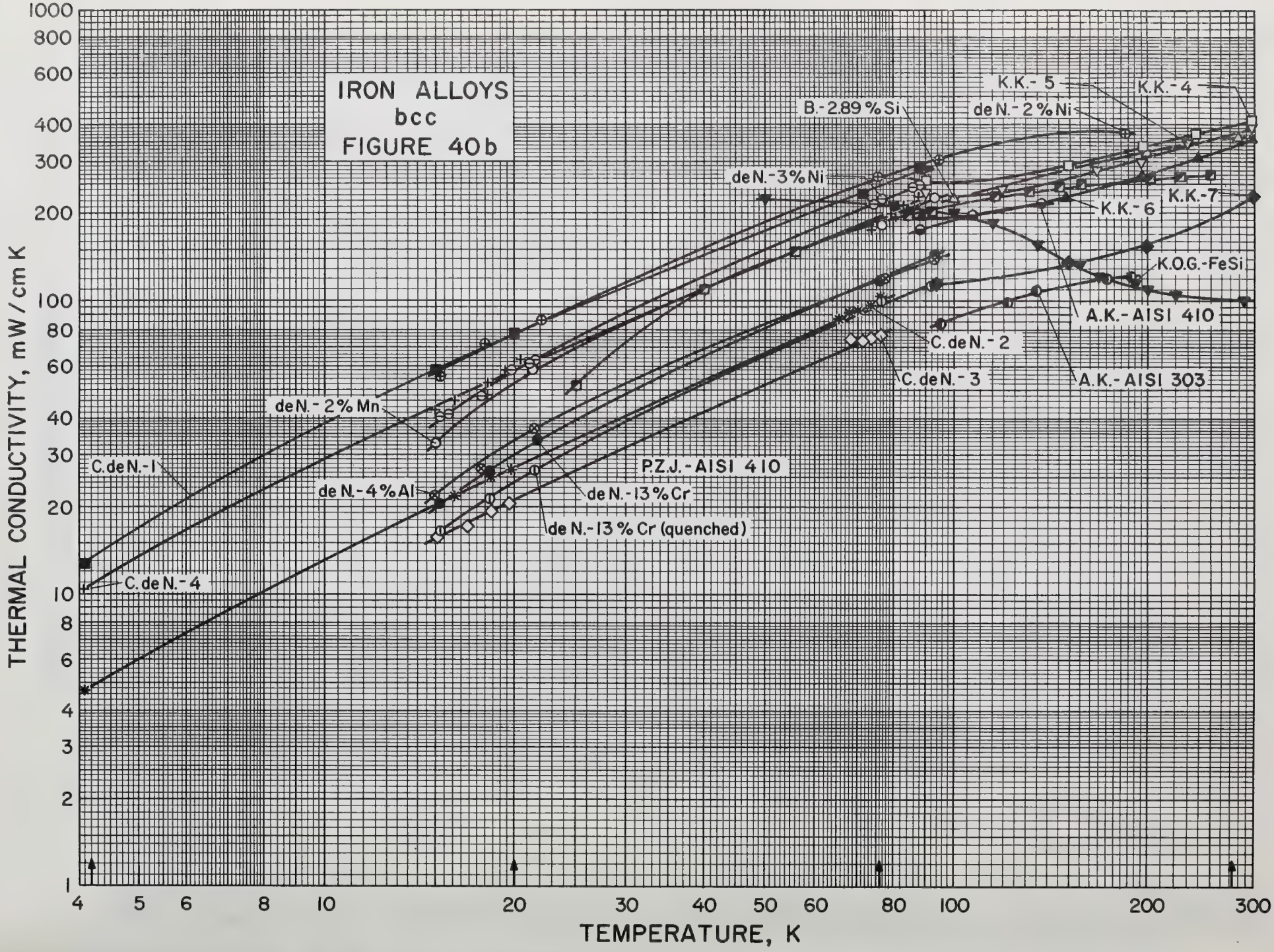
<1% other metals

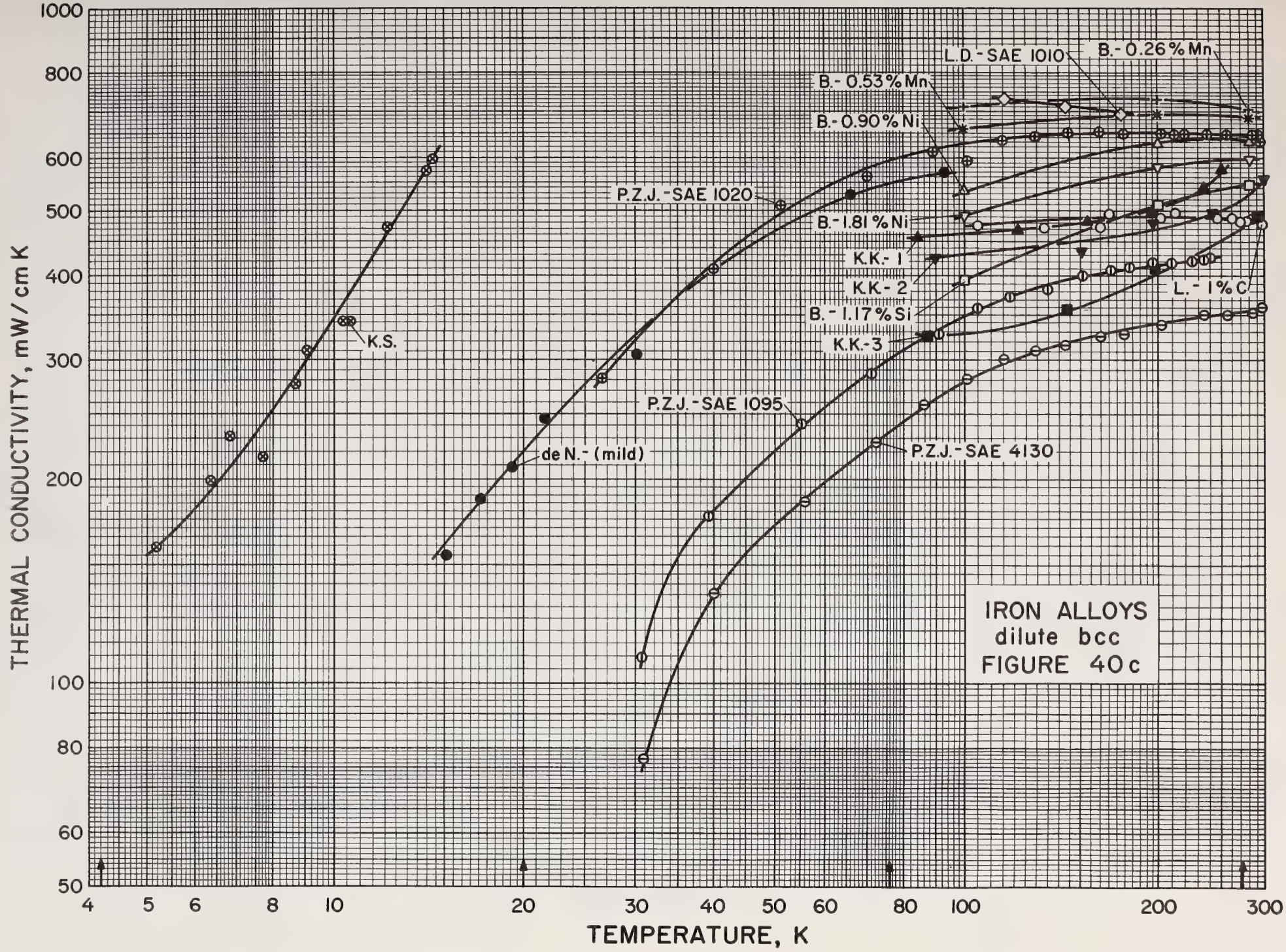
Stainless steel

<1% C

>5% Cr
usually Ni
} <25% either


IRON ALLOYS
fcc
FIGURE 40a
THERMAL CONDUCTIVITY, mW/cm K
TEMPERATURE, K
200
100
80
60
50
40
30
20
10
8
6
5
4
3
2
4
5
6
8
10
20
30
40
50
60
80
100
200
300
de N.-13% Mn
K.K.-8
K.K.-11
K.K.-9
K.K.-10
E.Z.-AISI 347
P.Z.J.-AISI 304
P.Z.J.-AISI 347
T.W.-AISI 316
A.K.-AISI 303
B.-Stainless
de N.-39% Mn
H.-AISI 347
de N.-31% Ni
C. de N.-5
de N.-27% Ni
de N.-36% Ni
de N.-13% Mn+1% C
Z.Z.-Stainless
E.Z.-AISI 303


IRON ALLOYS
bcc
FIGURE 40b
THERMAL CONDUCTIVITY, mW/cm K
TEMPERATURE, K
1000
800
600
400
300
200
100
80
60
40
30
20
10
8
6
4
3
2
1
4
5
6
8
10
20
30
40
50
60
80
100
200
300
K.K.- 5
K.K.- 4
B.- 2.89 % Si
deN.- 2 % Ni
deN.- 3% Ni
K.K.- 6
K.K.- 7
K.O.G.- FeSi
A.K.- AISI 410
C. deN.- 2
C. deN.- 3
A.K.- AISI 303
deN.- 2% Mn
C. deN.- 1
P.Z.J.- AISI 410
deN.- 4% Al
deN.- 13% Cr
deN.- 13 % Cr (quenched)
C. deN.- 4


THERMAL CONDUCTIVITY, mW/cm K
TEMPERATURE, K
1000
800
600
500
400
300
200
100
80
60
50
4
5
6
8
10
20
30
40
50
60
80
100
200
300
L.D.-SAE 1010
B.-0.26% Mn
B.-0.53% Mn
B.-0.90% Ni
P.Z.J.-SAE 1020
B.-1.81% Ni
K.K.-1
K.K-2
B.-1.17% Si
K.K.-3
L.-1% C
K.S.
P.Z.J.-SAE 1095
de N.-(mild)
P.Z.J.-SAE 4130
IRON ALLOYS
dilute bcc
FIGURE 40c

IRON ALLOYS

(See FIGURES 40a-40c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
		Iron alloy composition: > 25% any.		
. . . . .	. . . . .	See Kurnakov and Rakhmanovski (1937) in Chromium Alloys, Manganese Alloys, and Silicon Alloys for ferro-chromium, ferro-manganese, and ferro-silicon, respectively.	. . . . .	. . . . .
deN. -27% Ni	27.3 Ni, 14.6 Cr, 3.5 W, 1.62 Si, 1.34 Mn, 0.44 C.	"Era/ATV"; heated to 1000°C, water-quenched Brinell hardness of 220. See also alloy steels, carbon steels and cast irons, and stainless steels.	A-1; B-1; C-1; D-3(1); E-5; F-4; G-2; L-1; M-1.	J. deNobel (1951).
deN. -31% Ni	31.4 Ni, 0.82 Mn, 0.7 C.	Heated to 800°C, furnace-cooled; Brinell hardness of 147. See also alloy steels, carbon steels and cast irons, and stainless steels.	Same as above.	Same as above.
deN. -36% Ni	36.17 Ni, 0.92 Mn, 0.16 C, 0.09 Si.	Heated to 1050°C, water-quenched; Brinell hardness of 142. See also alloy steels, carbon steels and cast irons, and stainless steels.	A-1; B-1; C-1; D-2(2); E-5; F-4; G-2; L-1; M-1.	Same as above.
deN. -39% Mn	38.9 Mn, 0.7 Si, 0.2 C, 0.06S, 0.04 P.	Heated to 1000°C, water-quenched; Brinell hardness of 156. See also alloy steels, carbon steels and cast irons, and stainless steels.	A-1; B-1; C-1; D-4(1); E-5; F-4; G-2; L-1; M-1.	Same as above.
. . . . .	Firth Vickers; 36.5 Ni, 16.75 Cr, 1.9 Si, 0.58 Mn, 0.49 C, 0.16S, 0.12 P.	Macloy G steel; k = 103 mW/cm-K at 273 K. A specimen of Era A.T.V. steel had k = 109 mW/cm-K at 273 K. See also stainless steels.	A-1; B-1; C-1; D-1(2); F-3; G-3; P-1; S-1, 5.	R. W. Powell and R. P. Tye (1960).
K.O.G. -FeSi	Prepared from A-2 grade, 99.98 Fe, carbonyl iron and semiconductor grade silicon.	Single crystal; components melted in quartz crucible, placed in argon atmosphere in induction furnace; grown by Czochralski method; cut with diamond disk; ground; rod axis parallel to [210] growth axis. Graph of electronic and lattice thermal conductivity.	G-3; L-1; M-1; O-1; P-1; S-1, 2.	R. P. Krentis, F. I. Ostrovskii, and P. V. Gel'd (1970).

IRON ALLOYS (cont'd)

(See FIGURES 40a-40c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	Measured the change in thermal conductivity in Fe-Ni alloys in a magnetic field of up to 8 T in the temperature range 1.2-4.5 K to study the magnon conductivity. All values below are at room temperature.	. . . . .	W. B. Yelon and L. Berger (1970).
. . . . .	29 Ni, 17 Co	Nilo K; k = 190 mW/cm-K.	. . . . .	Alloy Digest.
. . . . .	28.70-29.20 Ni, 17.30-17.80 Mn, 0.50 Mn, 0.20 Si, 0.06 C	Kovar "A"; Rodar; k = 165 mW/cm-K.	. . . . .	Same as above.
. . . . .	41 Ni, 0.40-1.00 Mn, 0.25 Si, 0.08 C.	D-H No. 42; 42% Ni-Fe; Allegheny 42; Bethlehem No. 7; Carpenter No. 42; k = 160 mW/cm-K.	. . . . .	Same as above.
. . . . .	27 Ni, 25 Co	Ceramvar; k = 170 mW/cm-K.	. . . . .	Same as above.
. . . . .	49.0 Ni, 0.50 Mn, 0.35 Si, 0.05 C.	Carpenter High Permeability 49; k = 130 mW/cm-K.	. . . . .	Same as above.
. . . . .	26.0-28.5 Co, 0.80 Mn, 0.75 Cr and Ni, 0.45 Si.	Hiperco 27; k = 547 mW/cm-K.	. . . . .	Same as above.

CARBON STEELS AND CAST IRONS

(See FIGURES 40a-40c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
		Carbon steel composition: 0.1-2% C, <0.5% Si, Mn, <1% other metals. Cast iron composition: 2.4% C, 1-5% Si, <1% other metals.		
. . . . .	0.1 C.	Wrought iron; drawn; k = 670 mW/cm-K at 18°C; specific density of 7.84.	A-4; B-1; C-2, 3; D-1(3); E-1; F-4; G-3; S-1, 2, 3, 5.	W. Jaeger and H. Diesselhorst (1900).
. . . . .	1 C.	Wrought iron; drawn; k = 453 mW/cm-K at 18°C; specific density of 7.82.	Same as above.	Same as above.
. . . . .	0.1 C, 0.2 Si, 0.1 Mn, trace of Cu, P, and S.	k = 600 mW/cm-K at 18°C.	Same as above.	Same as above.
. . . . .	0.105 C, 0.06 Mn, 0.03 P, 0.015 S and Si.	k = 720 mW/cm-K at 18°C. Specific density of 7.87.	A-1; B-1; C-2; D-1(2); F-5; G-3; S-1, 3, 5.	E. Grüneisen (1900).
. . . . .	0.57 C, 0.21 Si, 0.12 Mn, 0.042 S, 0.012 P.	k = 520 mW/cm-K at 18°C. Specific density of 7.83.	Same as above.	Same as above.
. . . . .	0.99 C, 0.12 Mn, 0.06 Si, 0.025 S, 0.005 P.	k = 510 mW/cm-K at 18°C. Specific density of 7.84.	Same as above.	Same as above.
. . . . .	1.50 C, 0.19 Mn, 0.05 Si, 0.025 S, 0.01 P.	k = 500 mW/cm-K at 18°C. Specific density of 7.81.	Same as above.	Same as above.
L. -1% C.	~1 C.	"Silver steel"; specific density of 7.84 at 24°C. The following measurements are at 25°C.	A-1; B-1; C-1; D-2(2); E-2; F-4; G-3; L-1; S-1, 5.	C. H. Lees (1908).
. . . . .	2.41 C, 0.12 Si, 0.09 S, 0.05 Mn, 0.04 P.	As cast; k = 320 mW/cm-K. Then annealed 2 hrs at 1000°C; k = 330. Then annealed 6 hrs at 1000°C; k = 330. Then annealed 8 hrs at 1000°C; k = 330.	A-4; B-1; C-2; D-1(3); F-5; G-3.	H. Masumoto (1927).
. . . . .	2.53 C, 0.05 Si, 0.03 S, 0.02 Mn, 0.01 P.	As cast; k = 310 mW/cm-K.	Same as above.	Same as above.
. . . . .	2.67 C, 0.11 Si, 0.05 S, 0.03 P, 0.02 Mn.	As cast; k = 300 mW/cm-K. Then annealed 2 hrs at 1000°C; k = 320. Then annealed 6 hrs at 1000°C; k = 320. Then annealed 8 hrs at 1000°C; k = 320.	Same as above.	Same as above.
. . . . .	3.12 C, 0.06 S and Si, 0.05 Mn, 0.02 P.	As cast; k = 260 mW/cm-K.	Same as above.	Same as above.
. . . . .	3.14 C, 0.03 Mn and S, 0.02 P, 0.01 Si.	As cast; k = 260 mW/cm-K.	Same as above.	Same as above.

CARBON STEELS AND CAST IRONS (cont'd)

(See FIGURES 40a-40c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	3.17 C, 0.21 Si, 0.08 Mn, 0.06 S, 0.04 P.	As cast; k = 250 mW/cm-K. Then annealed 2 hrs at 1000°C; k = 260. Then annealed 6 hrs at 1000°C; k = 260. Then annealed 8 hrs at 1000°C; k = 270.	A-4; B-1; C-2; D-1(3); F-5; G-3.	H. Masumoto (1927).
. . . . .	3.53 C, 0.05 Mn and S, 0.04 Si, 0.01 P.	As cast; k = 230 mW/cm-K.	Same as above.	Same as above.
. . . . .	3.64 C, 0.16 Si, 0.04 Mn, 0.02 P and S.	As cast; k = 210 mW/cm-K. Then annealed 2 hrs at 1000°C; k = 230. Then annealed 6 hrs at 1000°C; K = 230. Then annealed 8 hrs at 1000°C; k = 230.	Same as above.	Same as above.
. . . . .	3.93 C, 0.15 Si, 0.05 S, 0.04 Mn, 0.02 P.	As cast; k = 200 mW/cm-K.	Same as above.	Same as above.
. . . . .	3.96 C, 0.2 Si, 0.06 Mn, 0.02 S, 0.01 P.	As cast; k = 190 mW/cm-K. Then annealed 2 hrs at 1000°C; k = 210. Then annealed 6 hrs at 1000°C; k = 260. Then annealed 8 hrs at 1000°C; k = 500.	Same as above.	Same as above.
. . . . .	4.13 C, 0.10 Si, 0.03 Mn, 0.02 P and S.	As cast; k = 180 mW/cm-K. Then annealed 2 hrs at 1000°C; k = 200.	Same as above.	Same as above.
. . . . .	4.26 C, 0.10 Si, 0.03 Mn, 0.02 P and S.	As cast; k = 170 mW/cm-K. Then annealed 2 hrs at 1000°C; k = 190.	Same as above.	Same as above.
. . . . .	4.35 C, 0.35 Si, 0.08 Mn, 0.02 P and S.	As cast; k = 150 mW/cm-K. Then annealed 2 hrs at 1000°C; k = 570.	Same as above.	Same as above.
. . . . .	4.40 C, 0.34 Si, 0.08 S, 0.03 Mn, 0.02 P.	As cast; k = 150 mW/cm-K. Then annealed 2 hrs at 1000°C; k = 170.	Same as above.	Same as above.
. . . . .	4.61 C, 0.37 Si, 0.045 S, 0.03 Mn, 0.02 P.	As cast; k = 130 mW/cm-K. Then annealed 2 hrs at 1000°C; k = 150.	Same as above.	Same as above.
. . . . .	4.63 C, 0.54 Si, 0.08 Mn, 0.07 S, 0.02 P.	As cast; k = 130 mW/cm-K. Then annealed 2 hrs at 1000°C; k = 560.	Same as above.	Same as above.
. . . . .	3.82 C, 1.24 Si, 0.09 Mn, 0.06 S, 0.01 P.	As cast; k = 130 mW/cm-K. Then annealed 1 hr at 800°C; k = 200.	Same as above.	Same as above.
. . . . .	3.81 C, 1.96 Si, 0.05 Mn and S.	As cast; k = 130 mW/cm-K. Then annealed 1 hr at 800°C; k = 350. Then annealed 1 hr at 1000°C; k = 400.	Same as above.	Same as above.
. . . . .	3.84 C, 1.95 Si, 0.06 Mn, 0.01 S.	As cast; k = 430 mW/cm-K. Then annealed 1 hr at 800°C; k = 520.	Same as above.	Same as above.
K.S.	Injekta; 0.5-0.7 Mn, 0.4 C, 0.2-0.35 Si, <0.03 P and S.	. . . . .	A-1; B-1; C-1; D-1(2); E-4, 5; F-4; G-3; M-1; S-1, 5.	J. Karweil and K. Schäfer (1939).

CARBON STEELS AND CAST IRONS (cont'd)

(See FIGURES 40a-40c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
deN. -(mild)	0.14 C, 0.08 Si, 0.07 Mn.	"Mild steel"; heated to 800°C and furnace-cooled; Brinell hardness of 104. See also alloy steels, iron alloys, and stainless steels.	A-1; B-1; C-1; D-4(1); E-5; F-4; G-2; L-1; M-1.	J. deNobel (1951).
P. Z. J. -SAE 1020, SAE 1095	SAE 1020: Carnegie Illinois Steel; 0.33 Mn, 0.18 C, 0.014 Si. SAE 1095; 0.93 C, 0.34 Mn, 0.26 Si, 0.1 Ni and Cr, 0.05 Mo.	See also alloy steels and stainless steels.	A-1; B-1; C-1; D-1(2); E-1; F-2; G-2; L-1, 2; M-1.	R. W. Powers, J. B. Ziegler, and H. L. Johnston (1951a).
L. D. -SAE 1010	United States Steel; nominal composition similar to that of P. Z. J. -SAE 1020.	Hot-rolled. See also stainless steels.	A-6; B-1; C-2; D-1(7); E-1; F-2; G-2; S-1, 3, 6.	C. F. Lucks and H. W. Deem (1958).
B. -0.26% Mn, 0.53% Mn, 0.93% Ni, 1.17 % Si, 3% Si.	Heraeus. #1: 0.26 Mn (may be attended with some impurity). #2: 0.53 Mn (may be attended with some impurity). #3: 0.90 Ni.	Melted in argon-atmosphere, rolled, annealed 2 hrs at 1100°C, rolled, annealed 10 hrs at 500°C. Graphs: electronic thermal resistivity as a function of temperature reciprocal; electronic thermal conductivity as a function of temperature; lattice thermal conductivity as a function of temperature; lattice thermal resistivity as a function of temperature; ratio of lattice and electronic thermal resistivities as a function of temperature. See also pure iron and alloy steels.	A-1; B-1; C-1; D-1(2); F-4; G-2; L-1, 2, 3; M-1; N-5; O-1; P-1, 3; Q-1, 5; S-1, 5.	N. G. Bäcklund (1961).
K. K. -1, 2, 3	#1: 0.46 Mn, 0.24 Si, 0.13 C, 0.09 Cr, 0.036 Aℓ, 0.027 S, 0.021 P, 0.005 N_2. #2: 0.53 Mn, 0.27 Si, 0.18 C, 0.09 Cr, 0.027 Aℓ and S, 0.019 P, 0.005 N_2. #3: 0.83 Mn, 0.52 Ni, 0.32 Si, 0.22 Aℓ, 0.10 C, 0.076 Cr, 0.031 S, 0.016 P, 0.009 N_2.	#1: type TT St 35. #2: type TT St 45. #3: type 10 Mn Aℓ 4. Preparations - #1: 10 min in water at 920°C, 0.5 hr in air at 650°C; #2: same as #1; #3: 0.25 hr at 950°C, 0.5 hr in air at 750°C. See also pure iron, alloy steels, and stainless steels.	A-1; B-1; C-1; D-1(3); F-4; G-2; L-1, 2; N-5; P-1; S-1, 5.	R. Kohlhaas and W. Kierspe (1965).
. . . . .	. . . . .	SAE 1020; values 5% greater than for P. Z. J. -SAE 1020. See also stainless steels.	. . . . .	J. G. Androvlakis and R. L. Kosson (1967).

CARBON STEELS AND CAST IRONS (cont'd)

(See FIGURES 40a-40c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
		All values below are at room temperature.		
. . . . .	0.95-1.05 C, 0.40-0.50 V, 0.20-0.35 Si, 0.10-0.30 Mn, 0.03 P and S.	Colhead; k = 450 mW/cm-K.	. . . . .	Alloy Digest (1952-68).
. . . . .	13.50-17.50 Ni, 5.50-7.50 Cu, 3.00 C, 1.00-2.80 Si, 1.75-2.50 Cr, 1.00-1.50 Mn.	Ni-Resist; k = 400 mW/cm-K.	. . . . .	Same as above.
. . . . .	>3.00 C, >1.00 Si.	Meehanite-GE; k = 420 mW/cm-K.	. . . . .	Same as above.
. . . . .	3.3-3.8 C, 2.0-3.0 Si, 0.2-0.6 Mn, 0-2.0 Ni, 0.08 P.	Ductalloy; k = 310 mW/cm-K.	. . . . .	Same as above.
. . . . .	3.15 C, 1.00 Si.	Meehanite H R; k = 520 mW/cm-K.	. . . . .	Same as above.
. . . . .	2.3-2.7 C, 0.8-1.5 Si, 0.55 Mn, 0.20 S, 0.18 P.	Malleable iron; k = 510 mW/cm-K.	. . . . .	Same as above.
. . . . .	18.0-22.0 Ni, 3.00 C, 1.75-3.00 Si, 1.75-2.50 Cr. 0.07-1.0 Mn, 0.08 P.	Ni-Resist ductile iron; k = 130 mW/cm-K.	. . . . .	Same as above.

ALLOY STEELS

(See FIGURES 40a-40c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
		Alloy steel composition: 0.1-1% C, 0.1 - 2% Si, 1-25% Mn or Ni, < 5% total Cr, Mo, and V.		
deN. -4% Aℓ.	4.11 Aℓ, 0.13 Si, 0.08 Mn, 0.03 C, 0.01 S.	Heated to 800°C and furnace-cooled; Brinell hardness of 144. See also carbon steels and cast irons, iron alloys, and stainless steels.	A-1; B-1; C-1; D-4(1); E-5; F-4; G-2; L-1; M-1.	J. deNobel (1951).
deN. -2% Ni.	1.92 Ni, 0.72 Mn, 0.21 Si, 0.14 C.	Heated to 800°C and furnace-cooled; Brinell hardness of 153. See also carbon steels and cast irons, iron alloys, and stainless steels.	Same as above.	Same as above.
deN. -3% Ni.	2.61 Ni, 0.75 Mo, 0.49 Cr, 0.45 Mn, 0.27 C, 0.11 Si, 0.03 P, 0.01 S.	Heated to 850°C, oil-quenched, reheated to 650°C, water-quenched; Brinell hardness of 330. See also carbon steels and cast irons, iron alloys, and stainless steels.	A-1; B-1; C-1; D-2(2); E-5; F-4; G-2; L-1; M-1.	Same as above.
deN. -2% Mn.	2.23 Mn, 0.41 C, 0.07 Si.	Heated to 800°C and furnace-cooled; Brinell hardness of 192. See also carbon steels and cast irons, iron alloys, and stainless steels.	A-1; B-1; C-1; D-4(1); E-5; F-4; G-2; L-1; M-1.	Same as above.
deN. -13% Mn + 1% C.	12.69 Mn, 1.27 C, 0.12 Si.	"Manganese steel"; heated to 2000°C and water-quenched; Brinell hardness of 202. See also carbon steels and cast irons, iron alloys, and stainless steels.	A-1; B-1; C-1; D-2(2); E-5; F-4; G-2; L-1; M-1.	Same as above.
deN. -13% Mn.	12.95 Mn, 0.12 Si, 0.10 S, 0.09 C, 0.05 P.	Heated to 1000°C and water-quenched; Brinell hardness of 323. See also carbon steels and cast irons, iron alloys, and stainless steels.	Same as above.	Same as above.
P. Z. J. -SAE 4130.	Carnegie Illinois Steel; 0.99 Cr, 0.52 Mn, 0.33 C, 0.25 Mo and Ni.	See also carbon steels and cast irons and stainless steels.	A-1; B-1; C-1; D-1(2); E-1; F-2; G-2; L-1, 2; M-1.	R. W. Powers, J. B. Ziegler and H. L. Johnston (1951a).

ALLOY STEELS (cont'd)
(See FIGURES 40a-40c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	1.05 C, 1.5 Cr, 0.73 Mn, 0.23 Ni and Si, 0.21 Mo, 0.030 P, 0.028 S.	En 31 (high C, Cr-Mo steel); 14% retained austenite; oil-quenched from 830°C: tempered at 140°C for 6 hrs, k = 225 mW/cm-K at 273 K; tempered at 750°C for 2 hrs, k = 375 mW/cm-K at 273 K; tempered at 350°C for 3 hrs, k = 320 mW/cm-K at 273 K; tempered at 550°C for 4 hrs, k = 335 mW/cm-K at 273 K; diamond pyramid hardness of 820, 240, 625, and 440, respectively.	A-1; B-1; C-1; D-1(2); G-3.	R. W. Powell and R. P. Tye (1956).
C. deN. -1, 2, 3, 4.	#1: 1.92 Ni, 0.72 Mn, 0.21 Si, 0.14 C. #2: 11.39 Ni, 0.93 Mn, 0.22 Si, 0.18 C. #3: 19.64 Ni, 1.09 Mn, 0.43 C. #4: 5.10 Ni, 0.34 Mn, 0.16 Si, 0.11 C, 0.041 P, 0.04 S.	#1-#4: types 1287D, 1287I, 1798H, and 3703, respectively. #1-#4: heated to 800°C and furnace-cooled; Brinell hardness of 153, 277, 179, and 157, respectively. Grain size: 48-96 (many inclusions, strongly lamellar), 96 (non-homogeneous, martensitic), 12-24 (austenitic, very homogeneous), and >96 grains/in^2 (many inclusions), respectively. Graph of electronic contribution to thermal conductivity. See also stainless steels.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-2; L-1, 2; M-1, 2; P-3; Q-1, 3; S-5.	M. S. R. Chari and J. deNobel (1959).
B. -1. 81% Ni.	Heraeus; 1.81 Ni.	Melted in argon-atmosphere, rolled, annealed 2 hrs at 1100°C, rolled, annealed 10 hrs at 500°C. Graphs: electronic thermal resistivity as a function of temperature reciprocal; electronic thermal conductivity as a function of temperature; lattice thermal conductivity as a function of temperature; lattice thermal resistivity as a function of temperature; ratio of lattice and electronic thermal resistivities as a function of temperature. See also pure iron and carbon steels and cast irons.	A-1; B-1; C-1; D-1(2); F-4; G-2; L-1, 2, 3; M-1; N-5; O-1; P-1, 3; Q-1, 5; S-1, 5.	N. G. Bäcklund (1961).

ALLOY STEELS (cont'd)
(See FIGURES 40a-40c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
K.K. -4, 5, 6, 7.	#4: 3.74 Ni, 0.45 Mn, 0.32 Si, 0.06 C. #5: 4.75 Ni, 0.40 Mn, 0.35 Si, 0.086 C. #6: 8.35 Ni, 0.74 Mn, 0.28 Si, 0.093 Cr, 0.051 C, 0.016 P, 0.009 N_2, 0.006 S. #7: 21.75 Mn, 3.55 Cr, 0.57 Si, 0.324 C.	#4: type 10Ni14. #5: type 12Ni19. #6: type X8Ni9. #7: X40MnCr 42. Preparations - #4: 0.5 hr at 850°C then 2 hrs at 600°C in air; #5: Same as #4; #6: 0.5 hr at 790°C then 3.5 hrs at 570°C in air; #7: 0.5 hr at 1050°C in air. Graphs of electronic and lattice components of thermal conductivity. See also pure iron, carbon steels and cast irons, and stainless steels. All values below are at room temperature.	A-1; B-1; C-1; D-1(3); F-4; G-2; L-1,2; N-5; P-1; S-1,5.	R. Kohlhaas and W. Kierspe (1965).
. . . . .	13.50-17.50 Ni, 5.50-7.50 Cu, 3.00 C, 1.00-2.80 Si, 1.75-2.50 Cr, 1.00-1.50 Mn.	Ni-Resist; k = 400 mW/cm-K.	. . . . .	Alloy Digest (1952-68).
. . . . .	18.00-22.00 Ni, 3.00 C, 1.75-3.00 Si, 1.75-2.50 Cr, 0.7-1.0 Mn, 0.08 P.	Ni-Resist ductile iron; k = 130 mW/cm-K.	. . . . .	Same as above.
. . . . .	4.10 Ni, 1.20 Aℓ, 0.30 Mn and Si, 0.25 Cr, 0.20 C and V.	Cascade; k = 360 mW/cm-K.	. . . . .	Same as above.
. . . . .	0.80 Cr, 0.50 C, 0.25 Si, 0.20 Mn and V.	Vanadium type "D"; k = 470 mW/cm-K.	. . . . .	Same as above.
. . . . .	0.90-1.10 Cr, 0.60-0.80 Mn, 0.45-0.55 C, 0.20-0.35 Si, 0.15-0.25 V.	Orion; k = 470 mW/cm-K.	. . . . .	Same as above.
. . . . .	5.00 Cr, 1.45 Mo, 1.20 W, 1.00 Si, 0.50 Mn, 0.35 C and V.	Pressurdie 2; k = 180 mW/cm-K.	. . . . .	Same as above.
. . . . .	1.00 Cr, 0.50 C, 0.25 V and W.	Hecla; k = 450 mW/cm-K.	. . . . .	Same as above.
. . . . .	9.00 W, 3.35 Cr, 0.30 C, Mn, and Si, 0.25 V.	Peerless-A; k = 250 mW/cm-K.	. . . . .	Same as above.
. . . . .	8.75-9.75 W, 3.00-3.50 Cr, 0.40-0.50 Si and V, 0.30-0.35 C, 0.20-0.35 Mn, 0.030 P, 0.025 S.	Latrobe C.L.W.; k = 250 mW/cm-K.	. . . . .	Same as above.
. . . . .	4.75 Cr, 1.20-1.40 Mo, 0.80-1.00 Si, 0.40-0.60 V, 0.20-0.40 Mn, 0.38-0.43 C.	Potomac A; k = 24 mW/cm-K.	. . . . .	Same as above.

ALLOY STEELS (cont'd)

(See FIGURES 40a-40c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	4.75-5.25 Cr, 1.35-1.70 Mo, 1.00-1.50 W, 0.80-1.20 Si, 0.32-0.38 C, 0.20-0.40 Mn, 0.10-0.50 V.	HWD No. 1; k = 173 mW/cm-K.	. . . . .	Alloy Digest (1952-68).
. . . . .	8.50-9.00 W, 3.25-3.60 Cr, 0.40-0.50 Si, 0.25-0.30 C, 0.20-0.40 Mn, 0.20-0.25 V.	Heppenstall T73; k = 250 mW/cm-K.	. . . . .	Same as above.
. . . . .	0.85-1.15 Cr, 0.65-0.95 Mn, 0.50-0.60 C, 0.45-0.60 Ni, 0.38-0.48 Mo, 0.20-0.35 Si, 0.06-0.10 V, 0.040 P and S.	Hardtem; k = 430 mW/cm-K.	. . . . .	Same as above.
. . . . .	5.00-5.50 Cr, 1.20-1.50 Mo, 0.90-1.20 Si, 0.40-0.60 V, 0.35-0.40 C, 0.30-0.50 Mn.	HWD-2; k = 173 mW/cm-K.	. . . . .	Same as above.
. . . . .	9.00-9.50 W, 1.75-2.25 Cr, 0.40-0.60 V, 0.33-0.38 C, 0.20-0.30 Mn and Si, 0.030 P and S.	Hotpress; k = 250 mW/cm-K.	. . . . .	Same as above.
. . . . .	4.75-5.25 Cr, 1.20-1.40 Mo, 0.80-1.00 Si, 0.4-0.6 V, 0.38-0.43 C, 0.20-0.40 Mn.	Dynaflex; k = 180 mW/cm-K.	. . . . .	Same as above.
. . . . .	9.50 W, 3.25 Cr, 0.40 V, 0.30 Mn and Si, 0.28 C.	Seneca Hot Die; k = 250 mW/cm-K.	. . . . .	Same as above.
. . . . .	0.90-1.20 Cr, 0.70-1.00 Mn, 0.50-0.60 C, 0.43-0.50 Mo, 0.20-0.35 Si, 0.10-0.15 V.	Heppenstall 6H55; k = 430 mW/cm-K.	. . . . .	Same as above.
. . . . .	1.50-2.0 Cr, 0.45-0.75 Mn, 0.45-0.50 C, 0.30 Si, 0.15-0.25 V.	Lominium; k = 470 mW/cm-K.	. . . . .	Same as above.
. . . . .	1.00 Cr, 0.30 Mn, 0.25 Mo, 0.15 Si, 0.07 C, B added.	Duramold B; k = 730 mW/cm-K.	. . . . .	Same as above.
. . . . .	11.00 W, 3.00 Cr, 0.40 V, 0.38 C, 0.25 Mn and Si.	Thermold H22; k = 250 mW/cm-K.	. . . . .	Same as above.
. . . . .	10.50-12.50 Mn, 7.00-8.50 Ni, 0.20-0.30 C.	Allegheny 88X; k = 136 mW/cm-K.	. . . . .	Same as above.
. . . . .	1.65-2.00 Ni, 0.70-0.90 Cr, 0.60-0.85 Mn, 0.38-0.43 C, 0.20-0.35 Si, 0.20-0.30 Mo, 0.040 P and S.	AISI 4340; similar to SAE 4340; k = 380 mW/cm-K.	. . . . .	Same as above.

ALLOY STEELS (cont'd)

(See FIGURES 40a-40c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	0.60-1.00 Mn, 0.40-0.70 Ni, 0.40-0.60 Cr, 0.38-0.43 C, 0.35-0.80 Si, 0.20-0.30 Mo, 0.040 P and S.	AISI 8740; equivalent to SAE 8740; k = 380 mW/cm-K.	. . . . .	Alloy Digest 1952-68).
. . . . .	0.80-1.10 Cr, 0.70-0.90 Mn, 0.48-0.53 C, 0.20-0.35 Si, 0.15 V, 0.040 P and S.	AISI 6150; k = 470 mW/cm-K.	. . . . .	Same as above.
. . . . .	1.10-1.40 Ni, 0.70-0.90 Mn, 0.55-0.75 Cr, 0.38-0.43 C, 0.20-0.35 Si, 0.04 P and S.	AISI 3140; equivalent to SAE 3140; k = 380 mW/cm-K.	. . . . .	Same as above.
. . . . .	0.70-0.90 Mn, 0.40-0.70 Ni, 0.40-0.60 Cr, 0.28-0.33 C, 0.20-0.35 Si, 0.15-0.25 Mo, 0.040 P and S.	AISI 8630; equivalent to SAE 8630; k = 380 mW/cm-K.	. . . . .	Same as above.
. . . . .	1.10-1.40 Ni, 0.60-0.80 Mn, 0.55-0.75 Cr, 0.28-0.33 C, 0.20-0.35 Si, 0.04 P and S.	AISI 3130; SAE 3130; ASTM A274; k = 380 mW/cm-K.	. . . . .	Same as above.
. . . . .	0.85-1.15 Ni, 0.70-0.90 Cr and Mn, 0.38-0.43 C, 0.20-0.35 Si, 0.20-0.30 Mo, 0.040 P and S.	AISI 9840; SAE 9840; k = 380 mW/cm-K.	. . . . .	Same as above.
. . . . .	0.70-0.90 Cr and Mn, 0.20-0.35 Si, 0.17-0.22 C, 0.10 V, 0.040 P and S.	AISI 6120; ASTM A331; k = 470 mW/cm-K.	. . . . .	Same as above.
. . . . .	1.80 Ni, 0.80 Cr, 0.70 Mn, 0.40 C, 0.30 Si, 0.25 Mo, 0.005 S, 0.003 P.	Ferrovac-4340; AISI 4340; ASTM A157-44; k = 380 mW/cm-K.	. . . . .	Same as above.
. . . . .	0.70-0.90 Cr and Mn, 0.38-0.43 C, 0.20-0.35 Si, 0.040 P and S.	AISI 5140; ASTM A274; k = 470 mW/cm-K.	. . . . .	Same as above.
. . . . .	0.90-1.10 Mo, 0.85-1.20 Cr, 0.60-0.80 Mn, 0.35 Si, 0.21 C, 0.15-0.30 V, 0.030 P, 0.025 S.	Chatillon 709; French AFNOR 18 CDV 4; k = 26 mW/cm-K.	. . . . .	Same as above.
. . . . .	0.90-1.20 Mn, 0.38-0.43 C, 0.30-0.60 Ni, 0.30-0.50 Cr, 0.20-0.35 Si, 0.08-0.15 Mo, 0.040 P and S.	AISI 9440; ASTM A304; k = 380 mW/cm-K.	. . . . .	Same as above.

ALLOY STEELS (cont'd)
(See FIGURES 40a-40c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	1.65-2.00 Ni, 1.45-1.80 Si, 0.65-0.90 Cr and Mn, 0.40-0.45 C, 0.30-0.45 Mo, 0.05 V, 0.025 P and S.	Alloy 300 M; k = 380 mW/cm-K.	. . . . .	Alloy Digest 1952-68).
. . . . .	1.75 Ni, 0.50 Mn, 0.25 Mo, 0.20 Si, 0.15 C, 0.03 P and S.	Impacto; AISI 4615; ASTM A322; k = 470 mW/cm-K.	. . . . .	Same as above.
. . . . .	0.70-0.90 Cr and Mn, 0.48-0.53 C, 0.20-0.35 Si, 0.040 P and S.	AISI 5150; ASTM A331; k = 470 mW/cm-K.	. . . . .	Same as above.
. . . . .	1.00-1.30 Cr, 0.70-1.00 Mn, 0.40-0.60 Mo, 0.38-0.48 C, 0.20-0.40 Si, 0.03 P and S.	Speed-cut; k = 430 mW/cm-K.	. . . . .	Same as above.
. . . . .	1.10-1.40 Ni, 0.60-0.80 Mn, 0.55-0.75 Cr, 0.20-0.35 Si, 0.17-0.22 C, 0.04 P and S.	AISI 3120; ASTM A274; k = 380 mW/cm-K.	. . . . .	Same as above.
. . . . .	11.50 Mn, 7.50 Ni, 0.50 Cr, 0.35 C.	Jessop No. 200; k = 136 mW/cm-K.	. . . . .	Same as above.
. . . . .	1.05 Mn, 0.70 Cr, 0.50 C, 0.20 Mo, 0.08 S.	Hy-ten "B" temper No. 3-X; k = 430 mW/cm-K.	. . . . .	Same as above.
. . . . .	1.00-1.50 Cr, 0.55-0.75 Si, 0.45-0.65 Mn, 0.40-0.60 Mo, 0.28-0.33 C, 0.20-0.30 V, 0.04 P and S.	Unitemp-14MV; k = 325 mW/cm-K.	. . . . .	Same as above.
. . . . .	0.80-1.10 Cr, 0.70-0.90 Mn, 0.43-0.48 C, 0.20-0.35 Si, 0.15 V, 0.040 P and S.	AISI 6145; ASTM A274; k = 470 mW/cm-K.	. . . . .	Same as above.
. . . . .	1.85-2.25 Ni, 1.00-1.35 Cr, 0.60-0.80 Mn, 0.50-0.70 Si, 0.38-0.43 C, 0.35-0.55 Mo.	Timken HS-260; k = 380 mW/cm-K.	. . . . .	Same as above.
. . . . .	0.75-1.00 Mn, 0.30-0.60 Ni, 0.30-0.50 Cr, 0.28-0.33 C, 0.20-0.35 Si, 0.08-0.15 Mo, 0.040 P and S.	AISI 94B30; k = 380 mW/cm-K.	. . . . .	Same as above.
. . . . .	1.25 Cr, 0.65 Si, 0.55 Mn, 0.50 Mo, 0.30 C, 0.25 V, 0.025 P and S.	Carpenter No. 709; AMS 6302; k = 430 mW/cm-K.	. . . . .	Same as above.

ALLOY STEELS (cont'd)
(See FIGURES 40a-40c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	0.70-1.3 Mn, 0.40-0.60 Si, 0.25-0.35 C and Mo, 0.15-0.60 Cr, 0.03-0.07 V, 0.003 B added.	Esco-12M; k = 470 mW/cm-K.	. . . . .	Alloy Digest 1952-68).
. . . . .	3.25-3.75 Ni, 0.60-0.80 Mn, 0.28-0.33 C, 0.20-0.35 Si, 0.040 P and S.	AISI 2330; ASTM A304, k = 660 mW/cm-K.	. . . . .	Same as above.
. . . . .	1.10 Mn, 0.40 C, 0.20 Si, 0.15 Mo, 0.080 S, 0.030 P.	Atlas CM; k = 370 mW/cm-K.	. . . . .	Same as above.
. . . . .	0.90 Mn, 0.44 C, 0.33 Cr, 0.08 S, 0.05 P, residual Si.	Hy-ten "B" temper No. 2; k = 470 mW/cm-K.	. . . . .	Same as above.
. . . . .	0.70-0.90 Mn, 0.35-0.45 Mo, 0.20-0.35 Si, 0.20-0.25 C, 0.040 P and S.	AISI 4422; k = 370 mW/cm-K.	. . . . .	Same as above.
. . . . .	1.0-1.5 Cr, 0.50-0.80 Mo, 0.40-0.70 Mn, 0.35-0.45 C, 0.35 Si, 0.05 P and S.	Durehete 900; ASTM A193-52T; k = 430 mW/cm-K.	. . . . .	Same as above.
. . . . .	1.10-1.40 Ni, 0.70-0.90 Cr and Mn, 0.48-0.53 C, 0.20-0.35 Si, 0.040 P and S.	AISI 3150; ASTM 322; k = 380 mW/cm-K.	. . . . .	Same as above.
. . . . .	1.0-1.5 Cr, 0.50-0.80 Mo, 0.40-0.70 Mn, 0.35 Si, 0.30-0.45 C, 0.20-0.30 V, 0.05 P and S.	Durehete 950; ASTM A193-52T; k = 430 mW/cm-K.	. . . . .	Same as above.
. . . . .	0.75-1.00 Mn, 0.40-0.70 Ni, 0.40-0.60 Cr, 0.40-0.45 C, 0.20-0.35 Si, 0.20-0.30 Mo, 0.040 P and S.	AISI 8742; ASTM A331; k = 380 mW/cm-K.	. . . . .	Same as above.
. . . . .	0.70-0.90 Mn, 0.20-0.35 Si, 0.20-0.30 Mo, 0.20-0.25 C, 0.040 P and S.	AISI 4023; k = 430 mW/cm-K.	. . . . .	Same as above.
. . . . .	0.45-0.65 Mn, 0.45-0.60 Mo, 0.20-0.35 Si, 0.18-0.23 C, 0.040 P and S.	Timken 4419; k = 430 mW/cm-K.	. . . . .	Same as above.
. . . . .	13.0-15.0 Mn, 2.75-3.25 Ni, 1.00 Si, 0.60-0.80 C, 0.10 P, 0.05 S.	Timang; k = 150 mW/cm-K.	. . . . .	Same as above.
. . . . .	1.15 Mn, 1.04 Cr, 0.30-0.35 C, 0.28 Si, 0.058 S, 0.022 P, 0.0025 B.	Speed alloy; k = 430 mW/cm-K.	. . . . .	Same as above.

ALLOY STEELS (cont'd)
(See FIGURES 40a-40c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	0.70-0.90 Mn, 0.60-0.90 Ni, 0.60 Si, 0.40-0.60 Cr, 0.30-0.38 C, 0.17-0.25 Mo, 0.04 P and S.	T-loy 34; AISI 8735; k = 380 mW/cm-K.	. . . . .	Alloy Digest 1952-68).
. . . . .	0.85-1.15 Cr, 0.65-0.95 Mn, 0.50-0.60 C, 0.45-0.60 Ni, 0.38-0.48 Mo, 0.20-0.35 Si, 0.04 P and S, 0.03 V added.	Heppenstall-5H50; k = 430 mW/cm-K.	. . . . .	Same as above.
. . . . .	1.65-2.00 Ni, 0.70-0.90 Cr, 0.60-0.85 Mn, 0.38-0.43 C, 0.20-0.35 Si, 0.20-0.30 Mo, 0.15-0.35 Pb, 0.04 P and S.	Hi-qua-led 43L40; k = 380 mW/cm-K.	. . . . .	Same as above.
. . . . .	1.65-2.00 Ni, 1.45-1.80 Si, 0.70-0.95 Cr, 0.65-0.90 Mn, 0.40-0.47 C, 0.30-0.45 Mo, 0.05 V.	Tricent; k = 380 mW/cm-K.	. . . . .	Same as above.

STAINLESS STEELS
(See FIGURES 40a-40c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
		Stainless steel composition: < 1% C, > 5% Cr, usually Ni, < 25% Cr or Ni.		
. . . . .	. . . . .	"Stainless steel"; k = 7, 11, and 15 mW/cm-K at 10, 15, and 20 K, respectively.	A-1; B-5; C-2; D-5(1); E-5; F-4; G-3; M-1.	K. R. Wilkinson and J. Wilks (1949).
deN. -27% Ni.	27.3 Ni, 14.6 Cr, 3.5 W, 1.62 Si, 1.34 Mn, 0.44 C.	"Era/ATV"; heated to 1000°C, water-quenched; Brinell hardness of 220. Another specimen of composition 24.3 Ni, 6.05 Mn, 1.18 C (Brinell hardness of 151) had nearly identical values. See also alloy steels, carbon steels and cast irons, and iron alloys.	A-1; B-1; C-1; D-4(1); E-5; F-4; G-2; L-1; M-1.	J. deNobel (1951).
deN. -13% Cr.	13.5 Cr, 0.36 C, 0.22 Si, 0.13 Mn.	Heated to 800°C and furnace-cooled; Brinell hardness of 265. See also alloy steels, carbon steels and cast irons, and iron alloys.	Same as above.	Same as above.
deNi. -13% Cr (quenched)	Same as above.	Heated to 950°C, oil-quenched, reheated to 450°C, air-cooled; Brinell hardness of 402. See also alloy steels, carbon steels and cast irons, and iron alloys.	Same as above.	Same as above.
. . . . .	18.8 Cr, 8.1 Ni, 0.43 Si, 0.24 Mn, 0.12 C.	Heated to 1150°C, water-quenched; Brinell hardness of 172; curve identical to deN. -36% Ni. See also alloy steels, carbon steels and cast irons, and iron alloys.	Same as above.	Same as above.
P. Z. J. -AISI 410	Carnegie Illinois Steel Corp.; 12.6 Cr, 0.36 Si, 0.32 Mn, 0.12 Ni, 0.09 C, 0.06 Cu, 0.03 N, 0.01 P.	See also alloy steels and carbon steels and cast irons.	A-1; B-1; C-1; D-1(2); E-1; F-2; G-2; L-1, 2; M-1.	R. W. Powers, J. B. Ziegler, and H. L. Johnston (1951a).

STAINLESS STEELS (cont'd)
(See FIGURES 40a-40c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
P. Z. J. -AISI 347	Carnegie Illinois Steel Corp.; 17.88 Cr, 10.28 Ni, 1.24 Mn, 0.85 Nb, 0.57 Si, 0.26 Cu, 0.06 C, 0.03 N, 0.02 P.	. . . . .	A-1; B-1; C-1; D-1(2); E-1; F-2; G-2; L-1, 2; M-1.	R. W. Powers, J. B. Ziegler, and H. L. Johnston (1951a).
P. Z. J. -AISI 304	Carnegie Illinois Steel Corp.; 18.68 Cr, 8.84 Ni, 1.12 Mn, 0.43 Si, 0.06 Cu, 0.05 C, 0.03 N, 0.02 P.	. . . . .	Same as above.	Same as above.
B. -Stainless	18.9 Cr, 7.9 Ni, 1 Ti, 0.7 Si, 0.1 C.	Austenitic steel; Austenite grains ~0.01 mm across; ferrite grains ~0.002 mm precipitated in grain boundaries of austenite. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-3, 4(2); E-4; F-4; G-2; P-1.	R. Berman (1951b).
E. Z. -AISI 303	18 Cr, 9 Ni, 0.15 C; RRR(22) = 1.44.	Stainless steel.	A-1; B-1; C-1; D-4(2); E-5; F-4; G-2; L-1, 2; M-1; S-1, 5.	I. Estermann and J. E. Zimmerman (1952).
E. Z. -AISI 347	18 Cr, 10 Ni, 0.5 Nb, 0.08 C; RRR(22) = 1.41.	Stainless steel. Nb-stabilized.	Same as above.	Same as above.
T. W. -AISI 316	Allegheny-Ludlum Steel Corp.; 17 Cr, 12 Ni, 2.5 Mo, 0.1 C.	Allegheny metal 18-8 M; 25% cold reduction; Brinell hardness of 255. Also measured a specimen of Type 304.	A-1; B-1; C-1; D-1(2); E-1; F-2; G-3;	W. W. Tyler and A. C. Wilson (1952).
Z. Z. -stainless	17-20 Cr, 8-11 Ni, 2.0 Mn, 0.8 Ti, 0.14 C, 0.035 P, 0.03 S.	Stainless steel, KH 18 NGT; not annealed; tubing.	A-1; B-3; C-1; D-3(2); E-3, 5; G-3; O-5.	N. V. Zavaritskii and A. C. Zeldovich (1956).
. . . . .	AISI 301: Republic Steel. AISI 316 and 347: Timken Roller Bearing.	All specimens: hot rolled, water-quenched. AISI 301: annealed 1 hr at 1038°C; values 10% greater than P. Z. J. -AISI 304 between 115 and 175 K. AISI 316: annealed 1 hr at 1093°C; values 15% greater than T. W. - AISI 316 between 115 and 175 K. AISI 347: annealed 1 hr at 1093°C; values 20% greater than P. Z. J. -AISI 347 between 115 and 175 K. See also carbon steels and cast irons.	A-6; B-1; C-2; D-1(7); E-1; F-2; G-2; S-1, 3, 6.	C. F. Lucks and H. W. Deem (1958).

STAINLESS STEELS (cont'd)
(See FIGURES 40a-40c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
C. deN-5.	#5: 18.80 Cr, 8.10 Ni, 0.43 Si, 0.24 Mn, 0.12 C.	#5: type 3754; heated to 1150°C, quenched in water; Brinell hardness of 172; grain size of 12-24 grains/in^2 (homogeneous, few inclusions). Graph of electronic contribution to thermal conductivity. See also alloy steels.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-2; L-1, 2; M-1, 2; P-3; Q-1, 3; S-5.	M. S. R. Chari and J. deNobel (1959).
. . . . .	. . . . .	Era ATV; k = 109 mW/cm-K at 273 K. See also iron alloys.	A-1; B-1; C-1; D-1(3); E-5; F-4; G-3.	R. W. Powell and R. P. Tye (1960).
K. K. -8, 9, 10, 11.	#8: 18.55 Cr, 11.5 Ni, 1.30 Mn, 0.70 Si, 0.07 Mo, 0.04 C, 0.016 N_2. #9: 17.16 Cr, 12.76 Ni, 1.37 Mn, 0.81 Nb, 0.50 Si, 0.28 Mo, 0.08 C, 0.035 N_2. #10: 15.8 Cr, 15.8 Ni, 1.93 Mo, 1.30 Mn, 0.84 Nb, 0.67 Si, 0.05 C, 0.001 N_2. #11: 16.88 Cr, 10.85 Ni, 1.94 Mo, 1.43 Mn, 0.37 Si, 0.27 Ti, 0.062 C.	#8: X5Cr Ni 18-9. #9: X8Cr Ni Nb 16-13. #10: X8Cr Ni Mo Nb 16-16. #11: X10Cr Ni Mo Ti 18-10. Preparations - #8 and #11: 0.5 hr at 1050°C in air; #9 and #10: 0.25 hr at 1100°C in air. Graphs of electronic and lattice components of thermal conductivity. See also pure iron, alloy steels, and carbon steels and cast irons.	A-1; B-1; C-1; D-1(3); F-4; G-2; L-1, 2; N-5; P-1; S-1, 5.	R. Kohlhaas and W. Kierspe (1965).
A. K. -AISI 303, AISI 410	. . . . .	Stainless steels. A specimen of AISI 321 had nearly identical values to AISI 303 between 85 and 160 K. See also carbon steels.	A-1; B-1; C-1; D-1(3); E-5; F-4; G-3.	J. G. Androulakis and R. L. Kosson (1967).
H. -AISI 347	17.16 Cr, 11.52 Ni, 1.34 Mn, 1.10 Ni + Ta, 0.59 Si, 0.057 C, 0.014 P, 0.007 S; RRR(7) = 1.37.	Cut from triple brazed conditioned nozzle; Rockwell hardness of B71; grain size of 0.0359 mm.	A-1; B-1; C-1; D-1(8); E-1, 2, 3; F-1; G-1; L-1; S-1, 2, 5.	J. G. Hust (1970).
. . . . .	. . . . .	Standard Reference Material austenitic stainless steel; approx. 10% greater than H. -AISI 347 at low and 5% greater at high temperatures. All values below are at room temperature.	Same as above.	J. G. Hust and L. L. Sparks (1971b).
. . . . .	33.00-37.00 Ni, 13.00-17.00 Cr, 2.50 Si, 2.00 Mn, 0.35-0.75 C.	Cromax; k = 130 mW/cm-K.	. . . . .	Alloy Digest (1952-68).
. . . . .	22.00 Cr, 5.00 Al, 1.00 Co, 0.10 C.	Kanthal-A; k = 169 mW/cm-K.	. . . . .	Same as above.

STAINLESS STEELS (cont'd)
(See FIGURES 40a-40c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	19.00-22.00 Ni, 7.00-9.00 Cr, 1.00-1.40 Si, 0.50-0.80 Mn, 0.10-0.20 C.	Cyclops 17B; AISI 325; ASTM A182; k = 195 mW/cm-K.	. . . . .	Alloy Digest (1952-68).
. . . . .	11.5-14.0 Cr, 1.00 Mn and Si, 0.75-1.25 Mo and W, 0.50-1.00 Ni, 0.18-0.25 C, 0.15-0.40 V.	Uniloy 1420 WM; k = 240 mW/cm-K.	. . . . .	Same as above.
. . . . .	22.6 Cr, 4.5 Aℓ, 1.0 Co, 0.09 C.	Kanthal-D; k = 170 mW/cm-K.	. . . . .	Same as above.
. . . . .	10.5 Cr, 0.92 Mn, 0.75 Mo, 0.45 Nb, 0.25 Ni, 0.16 Si, 0.15 V, 0.12 C.	Firth-Vickers 448; k = 240 mW/cm-K.	. . . . .	Same as above.
. . . . .	24.00-30.00 Ni, 19.00-21.00 Cr, 3.00-4.00 Cu, 2.00-3.00 Mo, 2.00 Mn, 1.00 Si, 0.07 C.	Carpenter Stainless No. 20; k = 210 mW/cm-K.	. . . . .	Same as above.
. . . . .	19.50 Cr, 9.0 Ni, 1.25 Si, 0.75 Mn, 0.08 C.	Donegal D-28; AISI (304) wrought; ASTM A351; k = 164 mW/cm-K.	. . . . .	Same as above.
. . . . .	16.00 Cr, 1.00 Cu, 0.75 Si, 0.25 Mn, 0.08 C.	Silcrome-RA; k = 330 mW/cm-K.	. . . . .	Same as above.
. . . . .	15.0 Cr, 5.0 Ni, 1.5 Cu and Mo, 0.05 C, 0-0.05 Nb or Ti.	Firth-Vickers FV.520; k = 160 mW/cm-K.	. . . . .	Same as above.
. . . . .	24.00-28.00 Ni, 12.00-15.00 Cr, 2.60-3.30 Ti, 1.75 Mn, 1.25-2.25 Mo, 0.08 C, 0.05-0.15 Aℓ, 0.025-0.12 B.	Westinghouse W545; k = 130 mW/cm-K.	. . . . .	Same as above.
. . . . .	18.0-23.0 Cr, 1.00 Mn and Si, 0.90-1.25 Cu, 0.20 C.	Carpenter Stainless No. 3; AISI 443; ASTM A268; k = 290 mW/cm-K.	. . . . .	Same as above.
. . . . .	33.00-37.00 Ni, 13.00-17.00 Cr, 2.50 Si, 2.00 Mn, 0.35-0.55 C.	Duraloy HT; AISI 330; ASTM A223; k = 2300 mW/cm-K.	. . . . .	Same as above.
. . . . .	17.0-19.0 Cr, 8.0-12.0 Ni, 2.00 Mn, 1.00 Si, 0.30-1.50 B, 0.08 C, 0.03 S.	Boron Stainless Steel; k = 140 mW/cm-K.	. . . . .	Same as above.
. . . . .	18.0 Ni, 16.0 Cr, 7.0 Co, 3.0 Mn, 2.5 Mo, 1.75 Nb, 0.80 Si, 0.25 C.	Firth-Vickers 326; k = 130 mW/cm-K.	. . . . .	Same as above.
. . . . .	11.50-14.00 Cr, 1.50 Si, 1.00 Mn, 0.75 Ni, 0.15 C, 0.04 P and S.	Cooper alloy 14S; AISI 410; ASTM A296; k = 250 mW/cm-K.	. . . . .	Same as above.

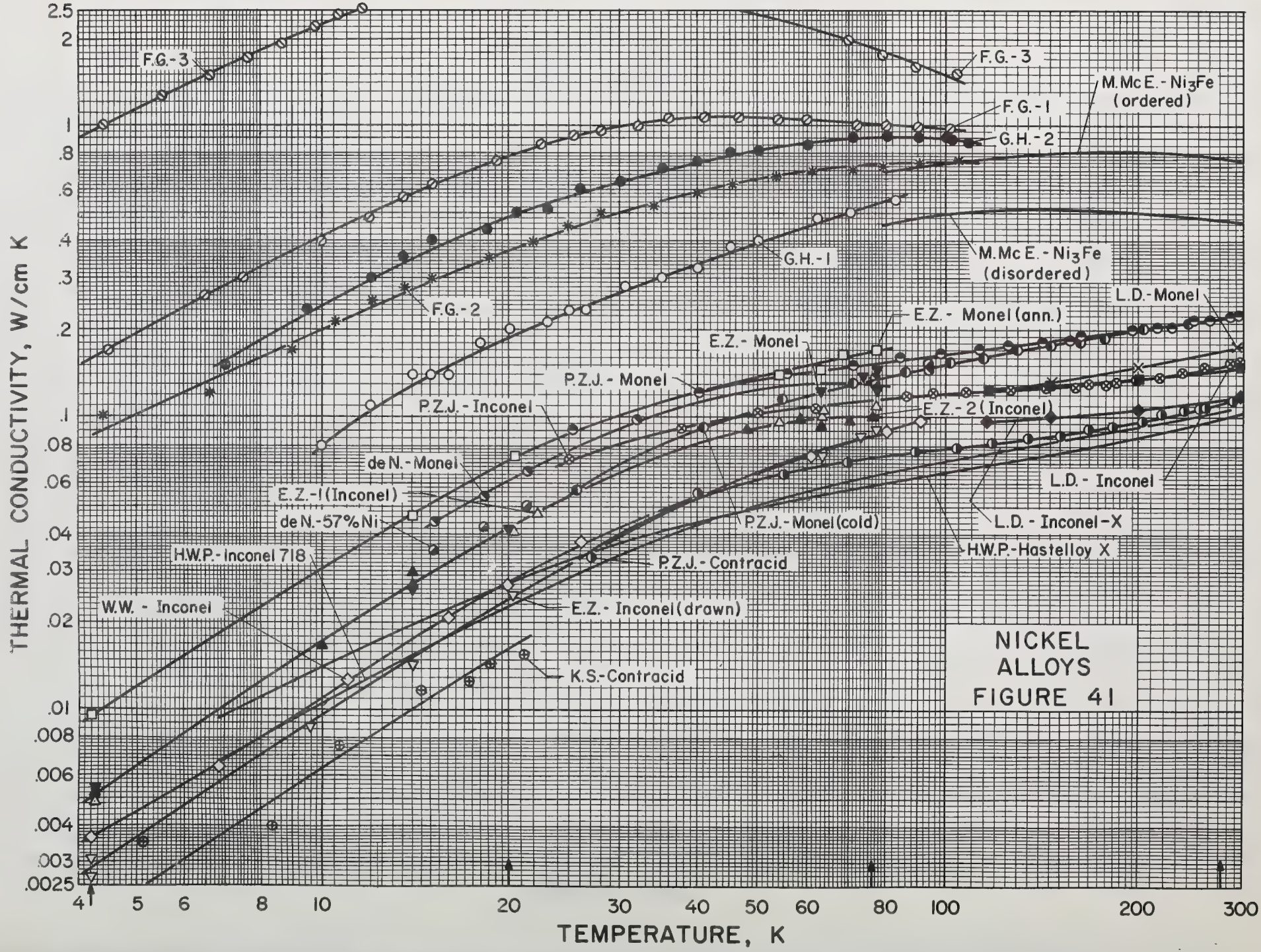
STAINLESS STEELS (cont'd)
(See FIGURES 40a-40c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	12.0-14.0 Cr, 1.25 Mn, 1.00 Si, 0.15 C and S, 0.06 P.	AISI 416; SAE 51416F; k = 230 mW/cm-K.	. . . . .	Alloy Digest (1952-68).
. . . . .	13.5-14.5 Cr, 5.0-5.8 Ni, 1.2-2.0 Cu and Mo, 1.0 Mn, 0.6 Si, 0.2-0.9 Nb, 0.07 C.	Firth-Vickers F.V.520B; k = 170 mW/cm-K.	. . . . .	Same as above.
. . . . .	16.50-17.50 Cr, 7.70-8.30 Ni, 1.00-1.50 Mn, 0.90-1.40 Si, 0.60-0.80 Mo, 0.07-0.11 C, 0.040 N_2, 0.025 P, 0.020 S.	Sandvik 11R51; k = 160 mW/cm-K.	. . . . .	Same as above.

USCOMM - ERL

COBALT ALLOYS

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	33.00 Cr, 17.00 W, 2.25 C, 2.00 Fe, 0.75 Si.	Rexalloy 33; k = 83 mW/cm-K.	. . . . .	Alloy Digest.
. . . . .	28.0 Ni, 20.0 Cr, 7.0 W, 4.0 Ti, 2.0 Fe, 0.20 C.	G. E. Alloy J-1570; k = 120 mW/cm-K.	. . . . .	Same as above.
. . . . .	27.0-31.0 Cr, 3.5-5.5 W, 3.0 Fe and Ni, 1.5 Mo and Si, 1.0 Mn, 0.9-1.4 C.	Haynes Stellite Alloy No. 6; ASTM-A-399-56T; k = 148 mW/cm-K.	. . . . .	Same as above.
. . . . .	19.00-21.00 Cr, 14.00-16.00 W, 9.00-11.00 Ni, 3.00 Fe, 1.00-2.00 Mn, 1.00 Si, 0.05-0.15 C, 0.040 P, 0.030 S.	Unitemp L-605; AMS 5537; k = 130 mW/cm-K.	. . . . .	Same as above.
. . . . .	30.0 Cr, 4.5 W, 3.0 Fe and Ni, 2.0 Mn and Si, 1.5 Mo, 1.1 C.	Haynes Stellite Alloy No. 6B; k = 148 mW/cm-K.	. . . . .	Same as above.
. . . . .	27-32 Cr, 14-19 W, 2-7 Nb + Ta, 2-5 Fe, 2-4 C, 1-3 Mn, 0.2 B.	Tantung G; k = 22 mW/cm-K.	. . . . .	Same as above.
. . . . .	33.00 Cr, 16.50 W, 2.00 C, 0.50 Mn and Si, present B and Fe.	ALX Alloy; k = 83 mW/cm-K.	. . . . .	Same as above.
. . . . .	26.00-30.00 Cr, 3.50-5.50 W, 3.00 Fe and Ni, 1.00-1.50 Si, 1.00 Mo, 0.90-1.40 C, 0.50 Mn.	Wallex No. 6; AMS 5788; ASTM-A399-56T; k = 148 mW/cm-K.	. . . . .	Same as above.
. . . . .	21.50-23.50 Ni, 1.55-1.95 Ti, 1.00 Fe, 0.45-0.80 Zr, 0.20-0.50 Mn, 0.15-0.30 Al, 0.10-0.25 Si, 0.05 C, 0.02 S, 0.01 P.	Nivco-10; k = 442 mW/cm-K.	. . . . .	Same as above.
. . . . .	27.0-29.0 Cr, 0.5-1.0 Si, 0.3-1.0 Mn, 0.05-0.12 C, 0.02 P and S.	UMCo-50; Waimet-50; k = 89 mW/cm-K.	. . . . .	Same as above.
. . . . .	19.85 Cr, 15.25 W, 9.90 Ni, 1.65 Mn, 1.60 Fe, 0.60 Si, 0.12 C.	AISI 670; AMS 5537; k = 94 mW/cm-K.	. . . . .	Same as above.
. . . . .	26.0-29.0 Cr, 1.5 Mn and Si, 0.10 C.	Esco Alloy 72; k = 89 mW/cm-K.	. . . . .	Same as above.


THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
2.5
2
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
.01
.008
.006
.004
.003
.0025
4
5
6
8
10
20
30
40
50
60
80
100
200
300
F.G.-3
F.G.-3
M.Mc E.-Ni3Fe (ordered)
F.G.-1
G.H.-2
M.Mc E.-Ni3Fe (disordered)
G.H.-1
F.G.-2
L.D.-Monel
E.Z.- Monel (ann.)
E.Z.- Monel
P.Z.J.- Monel
P.Z.J.- Inconel
E.Z.-2 (Inconel)
de N.-Monel
E.Z.-1 (Inconel)
de N.-57% Ni
L.D.- Inconel
L.D.- Inconel-X
P.Z.J.-Monel (cold)
H.W.P.-Hastelloy X
H.W.P.-Inconel 718
P.Z.J.-Contracid
W.W.- Inconel
E.Z.- Inconel (drawn)
K.S.-Contracid
NICKEL ALLOYS
FIGURE 41

NICKEL ALLOYS
(See FIGURE 41)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	97.0% Ni, 1.4 Co, 1 Mn, 0.4 Fe, 0.1 Cu and Si.	k = 0.59 at 18°C; specific density of 8.81.	A-4; B-1; C-2, 3; D-1(3); E-1; F-4; G-3; S-1, 2, 3, 5.	W. Jaeger and H. Diesselhorst (1900).
. . . . .	Prepared from Kahlbaum nickel and copper. 62.8 Ni, 37.2 Cu. 82.8 Ni, 17.2 Cu.	Rolled and drawn; heated 1/2 hr close to melting point. k = 0.22 at 0°C. k = 0.26 at 0°C.	. . . . .	E. Sedström (1919).
K. S.-Contracid	Heraeus; 60 Ni, 16 Fe, 15 Cr, 7 Mo .	Contracid B7M; drawn.	A-1; B-1; C-1; D-1(2); E-4, 5; F-4; G-3; M-1; S-1, 5.	J. Karweil and K. Schäfer (1939).
. . . . .	#1: 95.35 (weight) Ni, 0.26 Mn, 0.03 Fe, remaining Cu. #2: 90.98 Ni, 0.13 Mn, 0.04 Fe, remaining Cu. #3: 86.14 Ni, 0.10 Mn, 0.05 Fe, remaining Cu. #4: 78.20 Ni, 0.05 Fe and Mn, remaining Cu. #5: 69.56 Ni, 0.05 Mn, 0.03 Fe, remaining Cu. #6: 59.35 Ni, 0.07 Fe, 0.04 Mn, remaining Cu.	Values at 78 K - #1: k = 0.464; #2: k = 0.332; #3: k = 0.269; #4: k = 0.213; #5: k = 0.182; #6: k = 0.150.	A-1; B-1; C-1; D-1(2); E-2; F-4; G-3; M-2; S-1, 5.	S. Aoyama and T. Ito (1940).
. . . . .	Heraeus; 61.4 Ni, 18.5 Cr, 14.5 Fe, 3 Mn, 2 Mo, 0.6 Si.	Chroman B2Mo. k = 0.12 at 88 K; k = 0.046 at 70 K; k = 0.0026 at 3.9 K.	A-1; B-1; C-1; D-5(2); F-4; G-3.	F. Schmeissner and H. Meissner (1950).
P. Z. J.-Inconel, Contracid, Monel, Monel (cold)	Iconel: International Nickel Co.; 80 Ni, 14 Cr, 6 Fe. Contracid: General Electric; 60.05 Ni, 15.82 Fe, 14.74 Cr, 7.20 Mo, 2.14 Mn, 0.05 C. Monel: 67 Ni, 30 Cu, 1.4 Fe, 1.0 Mn, 0.15 C, 0.1 Si, 0.01 S. Monel (cold): International Nickel Co.; same as Monel.	Monel: hot-rolled. Monel (cold): cold-rolled.	A-1; B-1; C-1; D-1(2); E-1; F-2; G-2; L-1, 2; M-1.	R. W. Powers, J. B. Ziegler, and H. L. Johnston (1951c).

NICKEL ALLOYS (cont'd)

(See FIGURE 41)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Commercial; 99.4 Ni	See Nickel Table under "Elements".	. . . . .	J. de Nobel (1951).
de N.-Monel, 57% Ni.	Monel: 67.0 Ni, 30.2 Cu. 57% Ni: 57.5 Ni, 1.31 Mn, 0.34 C, 0.14 Si, remainder Fe (~40).	Monel: as forged; Brinell hardness of 197. 57% Ni: as forged; "A.M.F."; Brinell hardness of 177.	A-1; B-1; C-1; D-4(1); E-5; F-4; G-2; L-1; M-1.	Same as above
E.Z.-Inconel (drawn), 1(Inconel), 2(Inconel)	1 Inconel: RRR(22) = 1.006.	Inconel (drawn): hard-drawn tube. 1(Inconel): annealed tube. 2(Inconel): hot-rolled rod. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-4(2); E-5; F-4; G-2; L-1, 2; M-1; N-5; P-3, 4; S-1, 5.	I. Estermann and J. E. Zimmerman (1952).
E.Z.-Monel, Monel (ann.)	Monel: RRR(22) = 1.63; Monel (ann.): RRR(22) = 1.07.	Monel: cold-rolled, unannealed, hard drawn tubing; temper No. 3. Monel (ann.): annealed tubing; temper No. 1. Another specimen of monel rod also measured with values 30% lower at low temperatures and nearly the same at high temperatures as E.Z.-Monel. Graph of lattice thermal conductivity.	Same as above.	Same as above.
W.W.-Inconel	14-17 Cr, 6-10 Fe, 0.1 C, remainder Ni.	Hard-drawn; partially annealed as a result of soldering.	A-1; B-4; C-1; D-4(2); E-5; F-4; G-2.	G. K. White and S. B. Woods (1958 c).
L.D.-Inconel, Inconel-X, Monel	International Nickel Co.	Inconel: hot rolled; annealed 3 hrs at 1600°F, 15 min at 1800°F; air cooled. Inconel-X: hot rolled; solution treated 3 hrs at 2100°F; air cooled; double-aged 24 hrs at 1550°F, air cooled, 20 hrs at 1300°F, air cooled. Monel: Monel "K"; hot rolled, annealed 1 hr at 1650°F and water quenched.	A-6; B-1; C-2; D-1(7); E-1; F-2; G-2; S-1, 3, 6.	C. F. Lucks and H. W. Deem (1958).
. . . . .	Prepared from Johnson, Matthey nickel; 85.2 Ni, 14.8 Fe; RRR(20) = 3.5.	Melted in alumina crucible; annealed 2 hrs at 900°C, and 1 hr at 150°C; k = 0.0365 at 4.18 K; k = 0.0589 at 80.5 K; measured in transverse fields up to 2.2 T and longitudinal fields up to 1.8 T.	C-1; D-3(2); N-1, 2, 4, 6; S-1.	L. Berger and D. Rivier (1962).

NICKEL ALLOYS (cont'd)

(See FIGURE 41)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	17.0 (weight) Cr, 2.5 Al, 0.59 Ti, 0.36 Fe, 0.19 Si, 0.14 Cu, 0.08 Co, 0.066 C, 0.04 Mn, 0.004 S, 0.002 P.	Inconel 702; age hardened; annealed 24 hrs at 1150°C; cooled to room temperature in 8 hrs; k = 0.114 at 0°C.	A-6; B-1; C-1; D-1(15); F-1; G-2; L-1; M-1; O-1; S-1, 5.	M. J. Laubitz and K. D. Cotnam (1964).
G.H.-1,2	Prepared from Johnson, Matthey 890 Ni and 30 Cu; #1: 4.9 (atomic) Cu. #2: 1.6 Cu.	Chill cast; turned; annealed for 12 hrs at 850°C. #1: various sizes of grain and thickness of grain boundary. #2: long grains running in one direction; very thick (~0.05 mm) grain boundaries. See also FIGURE 16 and NICKEL Table under "Elements".	A-1; B-1; C-1; D-1(2); E-5; F-4; G-2; L-1, 2; N-1; S-1, 2, 5.	D. Grieg and J. P. Harrison (1965).
F.G.-1, 2, 3	#1: 4.7 (atomic) Co. #2: 4.6 Fe. #3: 0.80 Pd.	Table of intrinsic thermal resistivity. Other specimens of higher purity also measured; see FIGURE 16 and NICKEL Table in "Metallic Elements".	A-1; B-1; C-1; D-1(2); E-5; F-4; G-2; L-1, 2; M-1, 2; N-1, 5, 6; P-1; Q-1, 3; R-2; S-1, 5.	T. Farrell and D. Greig (1969).
H.W.P.-Inconel 718, Hastelloy X	Inconel 718: 54.57 (weight) Ni, 18.06 Cr, 17.08 Fe, 5.12 Nb + Ta, 3.18 Mo, 0.85 Ti, 0.44 Al, 0.29 Mn, 0.24 Si, <0.1C, Cu, and S; RRR(7) = 1.06. Hastelloy X: balance Ni, 21.06 (weight) Cr, 17.58 Fe, 9.15 Mo, 1.45 Co, 0.65 W, 0.53 Mn, 0.43 Si, 0.12 C, <0.1 P and S; RRR(27) = 1.06.	Inconel 718: age-hardened; structure of bcc + fcc precipitates; Rockwell hardness of C-39; average grain size of 0.06 mm. Hastelloy X: annealed; structure of bcc + fcc precipitates; Rockwell hardness of B-88; average grain size 0.08 mm.	A-1; B-1; C-1; D-1(8); E-1, 2, 3; F-1; G-1; L-1; M-1; N-1, 6; O-3; P-2, 4, 6; S-1, 2, 5.	J. G. Hust, D. H. Weitzel, and R. L. Powell (1970).
M. McE.-Ni_3Fe (ordered), Ni_3Fe (disordered)	74.7 (atomic) Ni, 25.1 Fe, <0.2 impurities.	Ni_3Fe (ordered): annealed isothermally at 602 K; long range order parameter ~0.96. Ni_3Fe (disordered): quenched from 1400 K in ice-water.	. . . . .	J. P. Moore, T. G. Kollie, R. S. Graves, and D. L. McElroy (1971).
. . . . .	56.00 Ni, 22.50 Cr, 6.50 Mn, 6.40 Mo, 6.00 Cu and Fe, 0.65 Si, 0.20 C.	Illium G; k = 0.120 at room temperature. All values below are at room temperature.	. . . . .	Alloy Digest (1952-68).
. . . . .	64.00 Ni, 22.00 Cr, 6.00 Fe, 5.00 Mo, 2.50 Cu, 0.30 Mn, 0.15 Si, 0.05 C.	Illium R; k = 0.120	. . . . .	Same as above.

NICKEL ALLOYS (cont'd)

(See FIGURE 41)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	65.00-68.00 Ni, 17.00-20.00 Cr, 1.00-1.75 Mn and Si, 0.50-0.55 C, balance Fe.	Calite "N"; k = 0.14	. . . . .	Alloy Digest (1952-68).
. . . . .	72.0 Ni, 14.0-17.0 Cr, 6.0-10.0 Fe, 1.00 Mn, 0.50 Cu and Si, 0.15 C, 0.015 S, small amount of Co.	Inconel; ASTM B166; k = 0.15.	. . . . .	Same as above.
. . . . .	40-44 Ni, 20-24 Co, 16-20 Cr, 1-4 Ti, 0.4-1.0 Mn and Si, 0.08 C, balance Fe.	K-42-B; k = 0.11.	. . . . .	Same as above.
. . . . .	97 Ni, 0.6 Fe, 0.5 Mn, 0.4 C, 0.35 Si, 0.25 Cu, 0.2-0.6 Ti, 0.01 S.	Permanickel; k = 0.58	. . . . .	Same as above.
. . . . .	18.0-20.0 Cr, 9.0-11.0 Co and Mo, 5.0 Fe, 2.25-2.75 Ti, 0.50-1.50 Mn, 0.50-1.25 Al, 0.30-1.00 Si, 0.10-0.20 C.	Alloy M252; k = 0.11.	. . . . .	Same as above.
. . . . .	58.0-62.0 Ni, 10.0-14.0 Cr, 2.50 Si, 2.00 Mn, 0.75 C, 0.040 P and S.	Misco HN-2; ACI Type HW; k = 0.14.	. . . . .	Same as above.
. . . . .	20.0 Cr, 10.0 Co and Mo, 3.0 Ti, 1.0 Al, 0.15 C.	G-E Alloy J-1500; M-252; k = 0.12.	. . . . .	Same as above.
. . . . .	18.0-20.0 Cr, 9.0-11.0 Co, 9.0-10.5 Mo, 5.0 Fe, 2.25-2.75 Ti, 0.75-1.25 Al, 0.50 Mn and Si, 0.10-0.20 C, 0.02-0.15 Zr, 0.001-0.01 B.	Unitemp M-252; k = 0.12.	. . . . .	Same as above.
. . . . .	14.0-17.0 Cr, 6.0-10.0 Fe, 1.50 Si, 1.0-2.0 Nb + Ta, 1.00 Mn, 0.50 Cu, 0.10 C, remainder Ni (+Co).	Circle Lin; Inconel; k = 0.15.	. . . . .	Same as above.
. . . . .	21.00-24.00 Cr, 8.00 Fe, 3.00-4.00 Cu, 2.00 Mn and Si, 1.75-2.25 Mo, 0.25 C.	Durco D-10; k = 0.12.	. . . . .	Same as above.
. . . . .	65.00-75.00 Ni, 12.00-18.00 Cr, 3.50-5.50 Fe and Si, 2.50-4.50 B, 0.50-1.00 C, 0.20 Co.	Colmonoy No. 6; ASTM A399-56T; k = 0.15.	. . . . .	Same as above.

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NICKEL ALLOYS (cont'd)

(See FIGURE 41)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	15.0-17.0 Cr, 8.0 Fe, 2.75-3.35 Ti, 2.0-2.50 Mn, 0.20 Cu, 0.15 Si, 0.10 Al, 0.01 S.	Inconel Alloy 721; k = 0.11	. . . . .	Alloy Digest (1952-68).
. . . . .	28.0-30.0 Mo, 3.0 Fe, 1.6-2.25 V, 0.2-1.0 Mn, 0.2-0.6 Si, 0.15-0.25 Cu, 0.05 C, remainder Ni (+Co).	Corronel 220; k = 0.11	. . . . .	Same as above.
. . . . .	11.5-13.5 W, 9.0-11.0 Co, 8.0-10.0 Cr, 4.75-5.25 Al, 1.75-2.25 Ti, 1.50 Fe, 0.75-1.25 Nb, 0.12-0.17 C, 0.03-0.08 Zr, 0.01-0.02 B.	SM-200; k = 0.14.	. . . . .	Same as above.
. . . . .	20.50-23.00 Cr, 17.00-20.00 Fe, 8.00-10.00 Mo, 1.00 Mn and Si, 0.50-2.50 Co, 0.20-1.00 W, 0.05-0.15 C, 0.04 P, 0.03 S.	Unitemp-HX; AISI 680; Hastelloy alloy X; k = 0.091.	. . . . .	Same as above.
. . . . .	31.5 Cu, 1.35 Fe, 0.90 Mn, 0.15 Si, 0.12 C, 0.005 S.	Monel alloy 400; k = 0.218.	. . . . .	Same as above.
. . . . .	14.0-17.0 Cr, 9.0-11.0 Fe, 4.5-6.5 Mo, 2.50 Co, 2.25-2.75 Ti, 1.75-2.25 Al, 0.60 Si, 0.25 Mn, 0.16 C, 0.030 S, 0.010 P.	Hastelloy alloy R-235; k = 0.109.	. . . . .	Same as above.
. . . . .	98 Ni, 2 ThO_2	TD-Nickel; k = 0.87	. . . . .	Same as above.
. . . . .	14.0-16.0 Cr, 13.0-17.0 Co, 4.5-5.5 Al, 3.5-4.5 Ti, 3.3-3.8 Mo, 0.12-0.20 C, 0.010-0.025 B, trace-0.25 Zr.	Nimonic alloy 115; k = 0.0042.	. . . . .	Same as above.
. . . . .	11.5-13.5 W, 9.00-11.00 Co, 8.00-10.00 Cr, 4.75-5.25 Al, 1.75-2.25 Ti, 1.50 Fe, 0.75-1.25 Nb, 0.20 Mn and Si, 0.12-0.17 C, 0.03-0.08 Zr, 0.01-0.02 B.	Mar-M alloy 200; k = 0.14.	. . . . .	Same as above.
. . . . .	38.0-46.0 Ni, 19.5-23.5 Cr, 2.5-3.5 Mo, 1.5-3.0 Cu, 1.0 Mn, 0.6-1.2 Ti, 0.5 Si, 0.2 Al, 0.05 C, 0.03 S, remainder Fe.	Incoloy alloy 825; k = 0.111.	. . . . .	Same as above.

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NICKEL ALLOYS (cont'd)

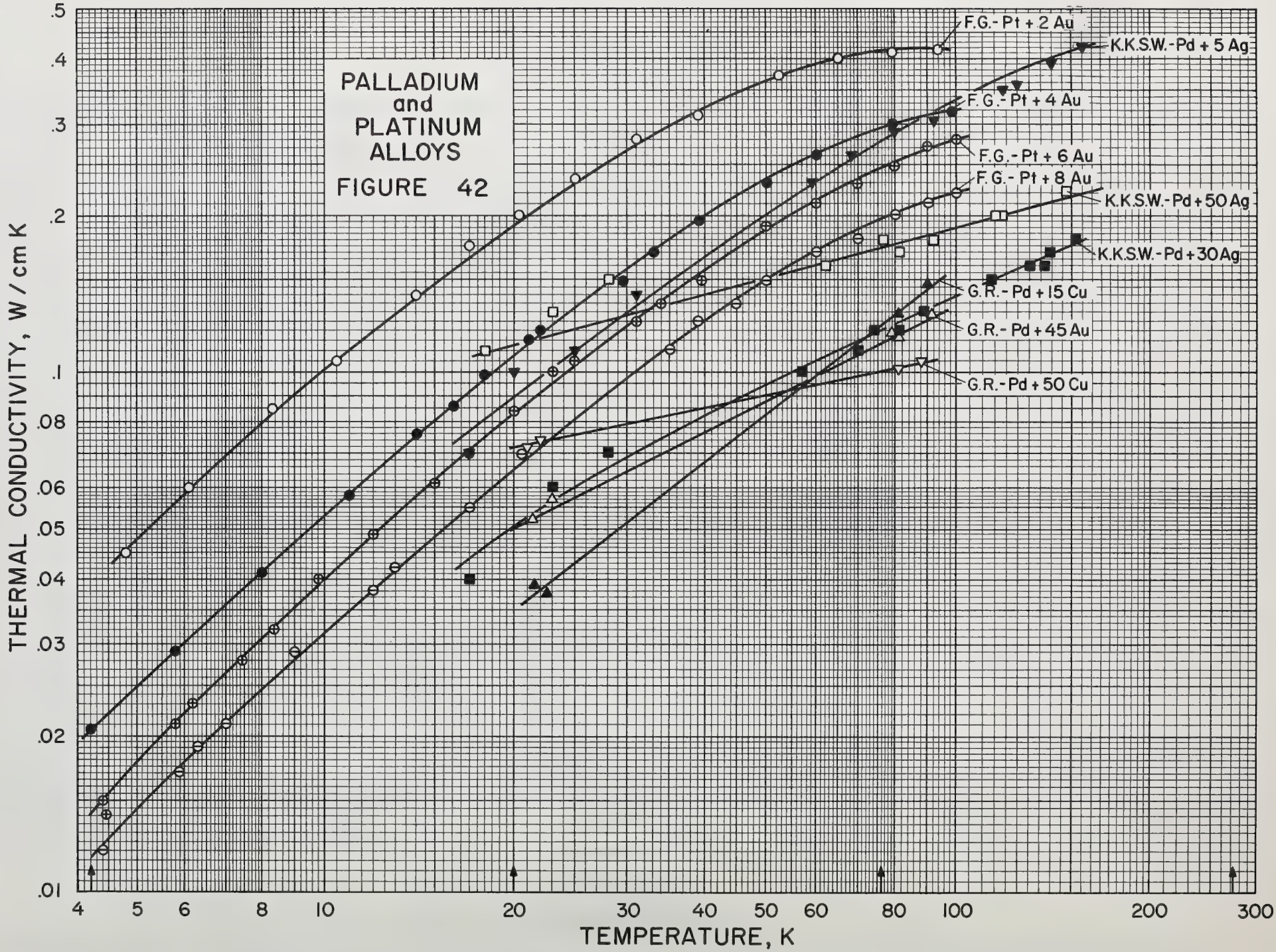
(See FIGURE 41)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	99.4 Ni + Co, 0.2 Mn, 0.15 Fe, 0.1 C and Cu.	A Nickel; ASTM B160-58T; k = 0.61.	. . . . .	Metals Handbook.
. . . . .	95 Ni, 4.5 Mn	D Nickel; ASTM F290-57T; k = 0.48	. . . . .	Same as above.
. . . . .	67 Ni, 30 Cu, 1.4 Fe, 1 Mn, 0.15 C, 0.1 Si.	Monel; ASTM B-127-58T; k = 0.26.	. . . . .	Same as above.
. . . . .	66 Ni, 29 Cu, 2.75 Al, 0.9 Fe, 0.75 Mn, 0.5 Si, 0.15 C.	K Monel; MIL-W-4471; k = 0.19.	. . . . .	Same as above.
. . . . .	57 Ni, 20 Mo, 20 Fe	Hastelloy A; k = 0.17.	. . . . .	Same as above.
. . . . .	62 Ni, 30 Mo, 5 Fe	Hastelloy B; k = 0.11.	. . . . .	Same as above.
. . . . .	58 Ni, 17 Mo, 15 Cr, 5 Fe and W.	Hastelloy C; k = 0.13.	. . . . .	Same as above.
. . . . .	85 Ni, 10 Si, 3 Cu	Hastelloy D; k = 0.21.	. . . . .	Same as above.
. . . . .	45 Ni, 55 Cu	Constantan; k = 0.23.	. . . . .	Same as above.
. . . . .	60 Ni, 24 Fe, 16 Cr	k = 0.14.	. . . . .	Same as above.
. . . . .	35 Ni, 50 Fe, 15 Cr	k = 0.13.	. . . . .	Same as above.

RUTHENIUM ALLOY

(See FIGURE 51a)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
M. -RuO_2	RRR = 115.	Grown using oxygen-transport deposition; specimen size of 0.09 x 0.165 x 4.0 mm; rod axis parallel to c-axis.	A-1; B-1; C-1; D-1(2); G-3; L-1; M-1; S-5.	J. Millstein (1970).


PALLADIUM
and
PLATINUM
ALLOYS
FIGURE 42
F.G. - Pt + 2 Au
K.K.S.W. - Pd + 5 Ag
F.G. - Pt + 4 Au
F.G. - Pt + 6 Au
F.G. - Pt + 8 Au
K.K.S.W. - Pd + 50 Ag
K.K.S.W. - Pd + 30 Ag
G.R. - Pd + 15 Cu
G.R. - Pd + 45 Au
G.R. - Pd + 50 Cu
THERMAL CONDUCTIVITY, W / cm K
.5
.4
.3
.2
.1
.08
.06
.05
.04
.03
.02
.01
4
5
6
8
10
20
30
40
50
60
80
100
200
300
TEMPERATURE, K

PALLADIUM ALLOYS

(See FIGURE 42)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Heraeus. #1: 90(weight) Pd, 10 Ag. #2: 80 Pd, 20 Ag. #3: 70 Pd, 30 Ag. #4: 60 Pd, 40 Ag. #5: 50 Pd, 50 Ag. #6: 90 Pd, 10 Au. #7: 80 Pd, 20 Au. #8: 70 Pd, 30 Au. #9: 60 Pd, 40 Au. #10: 50 Pd, 50 Au. #11: 90 Pd, 10 Pt. #12: 80 Pd, 20 Pt. #13: 70 Pd, 30 Pt. #14: 60 Pd, 40 Pt. #15: 50 Pd, 50 Pt.	Measured at 25°C. #1: k = 0.48. #2: k = 0.37. #3: k = 0.32. #4: k = 0.27. #5: k = 0.32. #6: k = 0.52. #7: k = 0.42. #8: k = 0.40. #9: k = 0.36. #10: k = 0.36. #11: k = 0.56. #12: k = 0.44. #13: k = 0.40. #14: k = 0.38. #15: k = 0.37.	A-4; B-1; C-3; G-2; M-2; S-1,5.	F.A. Schulze (1911).
. . . . .	Commercial	k = 0.42 at 17°C.	A-5; B-5; C-1; D-2(2); E-2; F-5; G-3; S-1.	T. Barratt (1914); see also T. Barratt and R.M. Winter (1925).
G.R.-85 Pd + 15 Cu, 50 Pd + 50 Cu, 55 Pd + 45 Au.	85 Pd + 15 Cu: Heraeus; 85.5 Pd, 14.5 Cu. 50 Pd + 50 Cu: Siebert; 50.1 Pd, 49.9 Cu. 55 Pd + 45 Au: Heraeus.	85 Pd + 15 Cu: polycrystalline. 50 Pd + 50 Cu: annealed. 55 Pd + 45 Au: annealed 2 hrs. at 800°C.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-3; L-1; M-2; P-1.	E. Grüneisen and H. Reddemann (1934).
K.K.S.W.-Pd + 5 Ag, Pd + 30 Ag, Pd + 50 Ag.	Johnson, Matthey. Pd + 50 Ag: 95(weight) Pd, 5 Ag; RRR(20) = 2.89. Pd + 30 Ag: 70 Pd, 30 Ag; RRR(20) = 1.15. Pd + 50 Ag: 50 Pd, 50 Ag; RRR(20) = 1.10.	Specimens annealed at 880°C. Specimens of Pd concentration < 50% also measured: see Silver Alloys Table and Figure. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-4(2); E-1, 5; F-4; G-1; L-1, 2, 9; M-2; N-5; P-2, 3; Q-1, 2; S-1, 5.	W.R.G. Kemp, P. G. Klemens, A.K. Sreedhar, and G. K. White (1956); see also Kemp, Klemens, Sreedhar, and White (1954).
. . . . .	Pd + compositions of 5, 10, 15, and 20 Ag.	Graph of lattice thermal conductivity.	. . . . .	R. Fletcher and D. Greig (1967).

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PLATINUM ALLOYS
(See FIGURE 42)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Heraeus; "impure."	k = 0.516 at 18°C; specific density of 21.32.	A-4; B-1; C-2, 3; D-1(3); E-1; F-4; G-3; S-1, 2, 3, 5.	W. Jaeger and H. Diesselhorst (1900).
. . . . .	Heraeus. #1: 90 Pt, 10 Pd. #2: 80 Pt, 20 Pd. #3: 70 Pt, 30 Pd. #4: 60 Pt, 40 Pd. #5: 50 Pt, 50 Pd.	Measured at 25°C. #1: k = 0.43. #2: k = 0.42. #3: k = 0.36. #4: k = 0.34. #5: k = 0.37.	A-4; B-1; C-3; G-2; M-2; S-1, 5.	F. A. Schulze (1911).
. . . . .	#1: 90 Pt, 10 Ir. #2: 85 Pt, 15 Ir. #3: 80 Pt, 20 Ir. #4: 90 Pt, 10 Rh.	#1: k = 0.31 at 17°C. #2: k = 0.23 at 17°C. #3: k = 0.18 at 17°C. #4: k = 0.30 at 17°C.	A-5; B-5; C-1; D-2(2); E-2; F-5; G-3; S-1.	T. Barratt (1914); See also T. Barratt and R. M. Winter (1925).
. . . . .	Heraeus. #1: 96 (atomic) Pt, 4 Au. #2: 90 Pt, 10 Au. #3: 75 Pt, 25 Au. #4: 55 Pt, 45 Au.	Melted; quenched in water; annealed at 800°C. #1: k = 0.46 at 18°C. #2: k = 0.35 at 18°C. #3: k = 0.24 at 18°C. #4: k = 0.21 at 18°C.	A-4; B-1; C-3; D-1(2); F-4; G-3; M-2; S-1, 2, 4.	C. H. Johansson and J. O. Linde (1930).
. . . . .	Pt + 9 W	Thermal conductivity measured between 1.3 - 4.2 K. Results expressed by equation: $k = (0.64\,T + 0.067\,T^3)\ 10^{-3}$ W/cm-deg.	. . . . .	A. J. Buhl and W. F. Giauque (1965).
F. G.-Pt + 2 Au, Pt + 4 Au, Pt + 6 Au, Pt + 8 Au	International Nickel Ltd. Pt + 2 Au: 2.00 (atomic) Au. Pt + 4 Au: 3.93 Au. Pt + 6 Au: 5.98 Au. Pt + 8 Au: 8.22 Au.	Annealed 2 hrs. at 1275°C, water-quenched. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-2; L-1; M-2; N-5; O-3, 5; P-2, 9; Q-1, 3; S-5.	R. Fletcher and D. Greig (1967).

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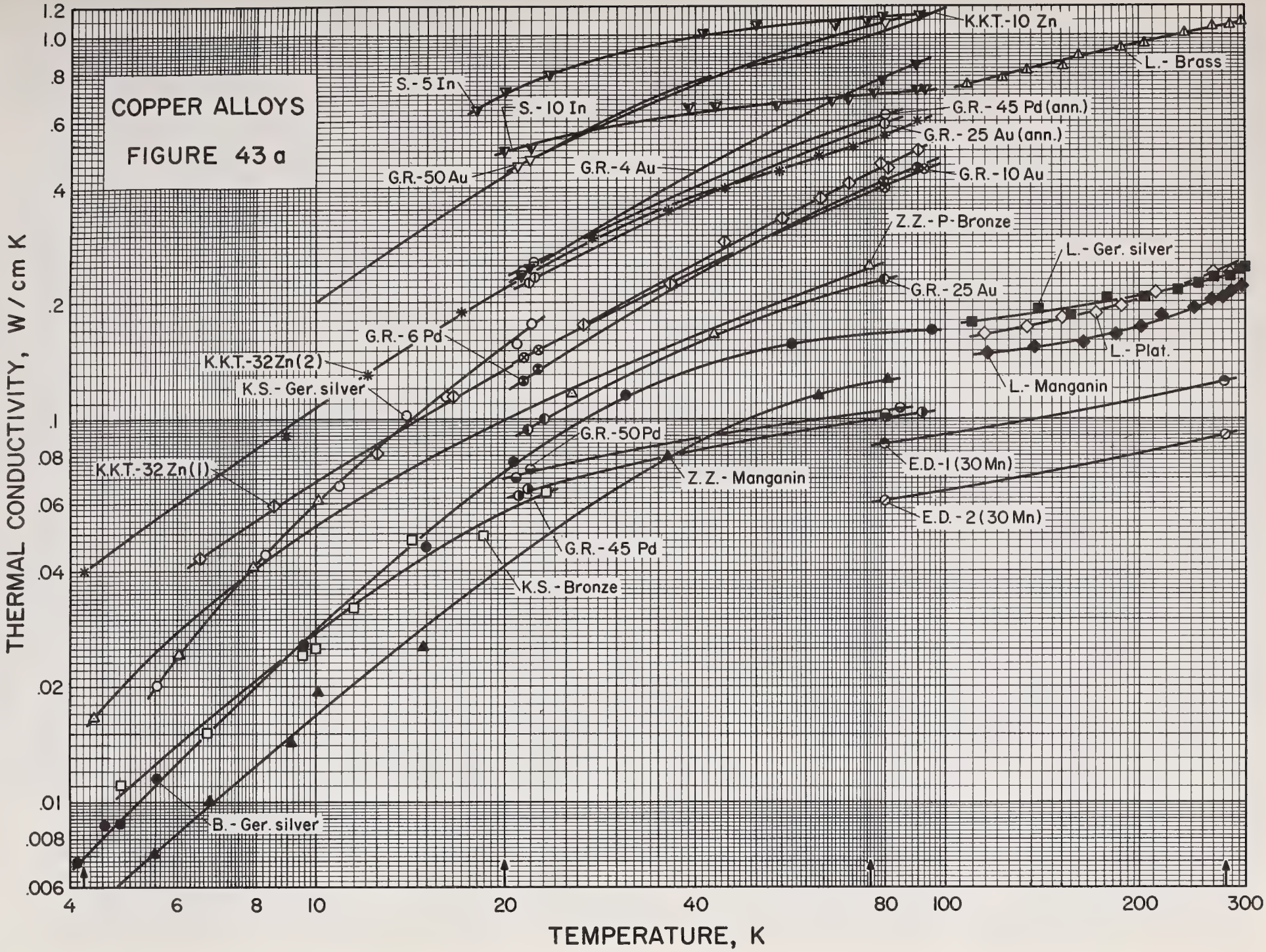
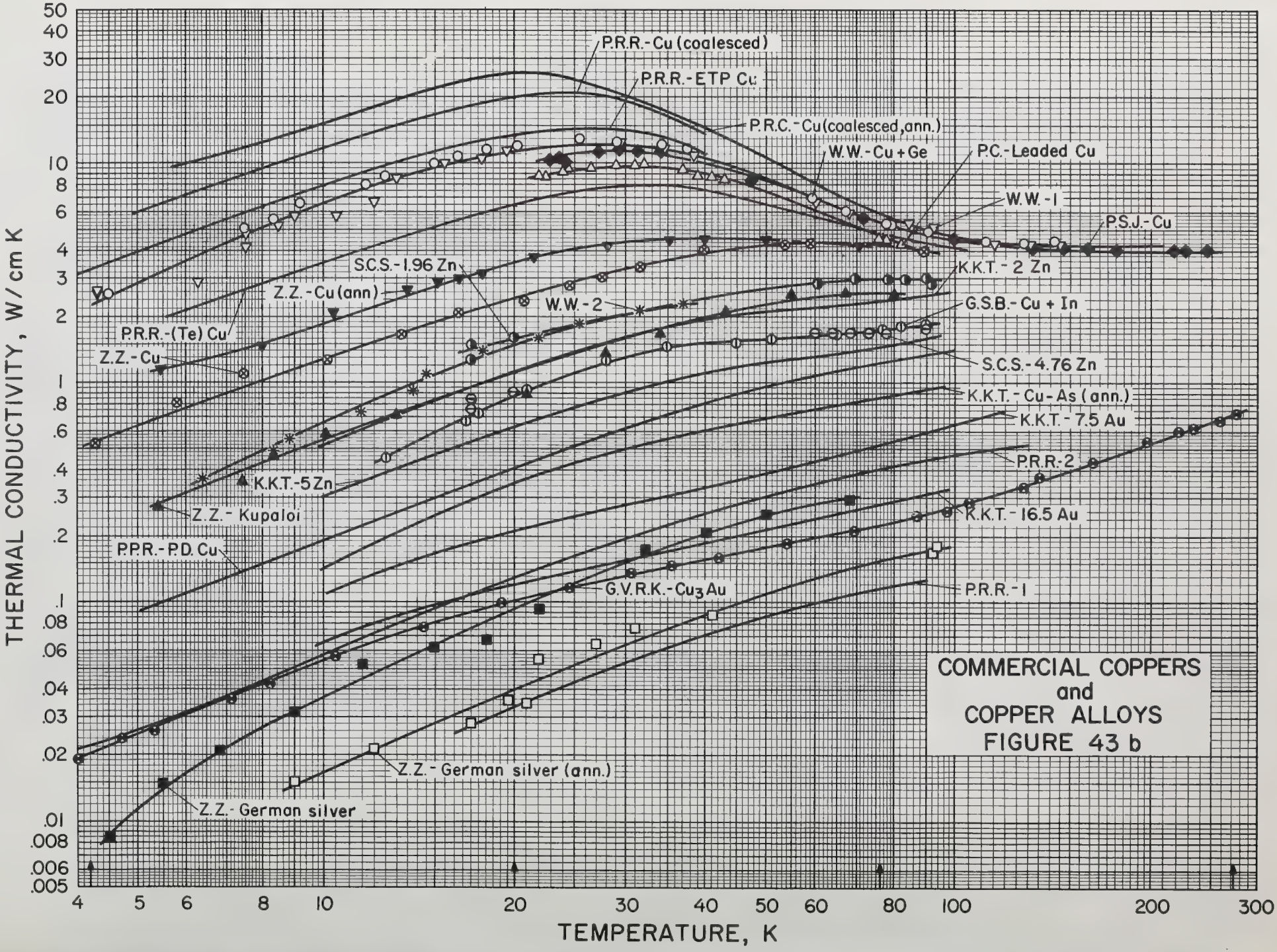
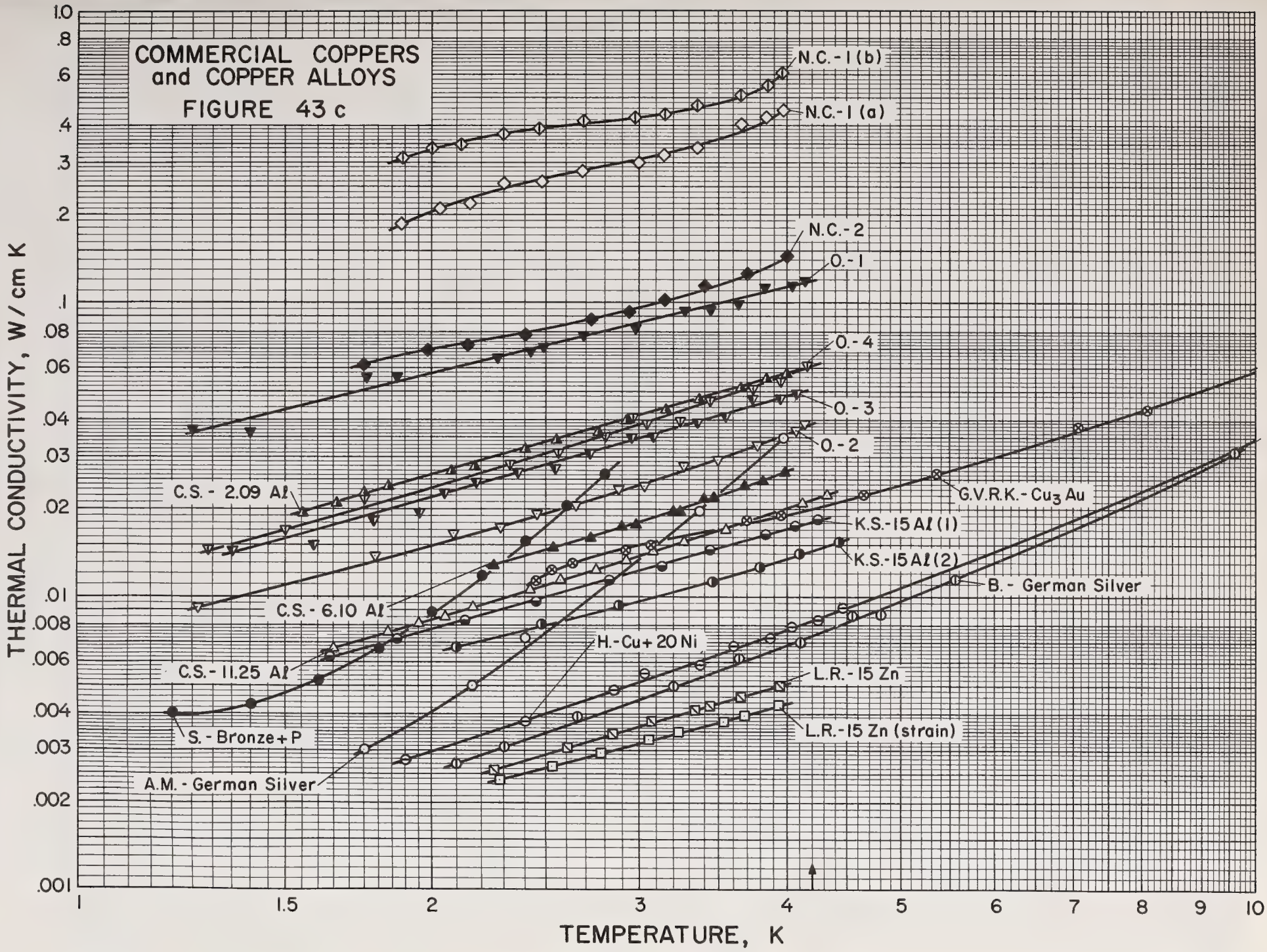
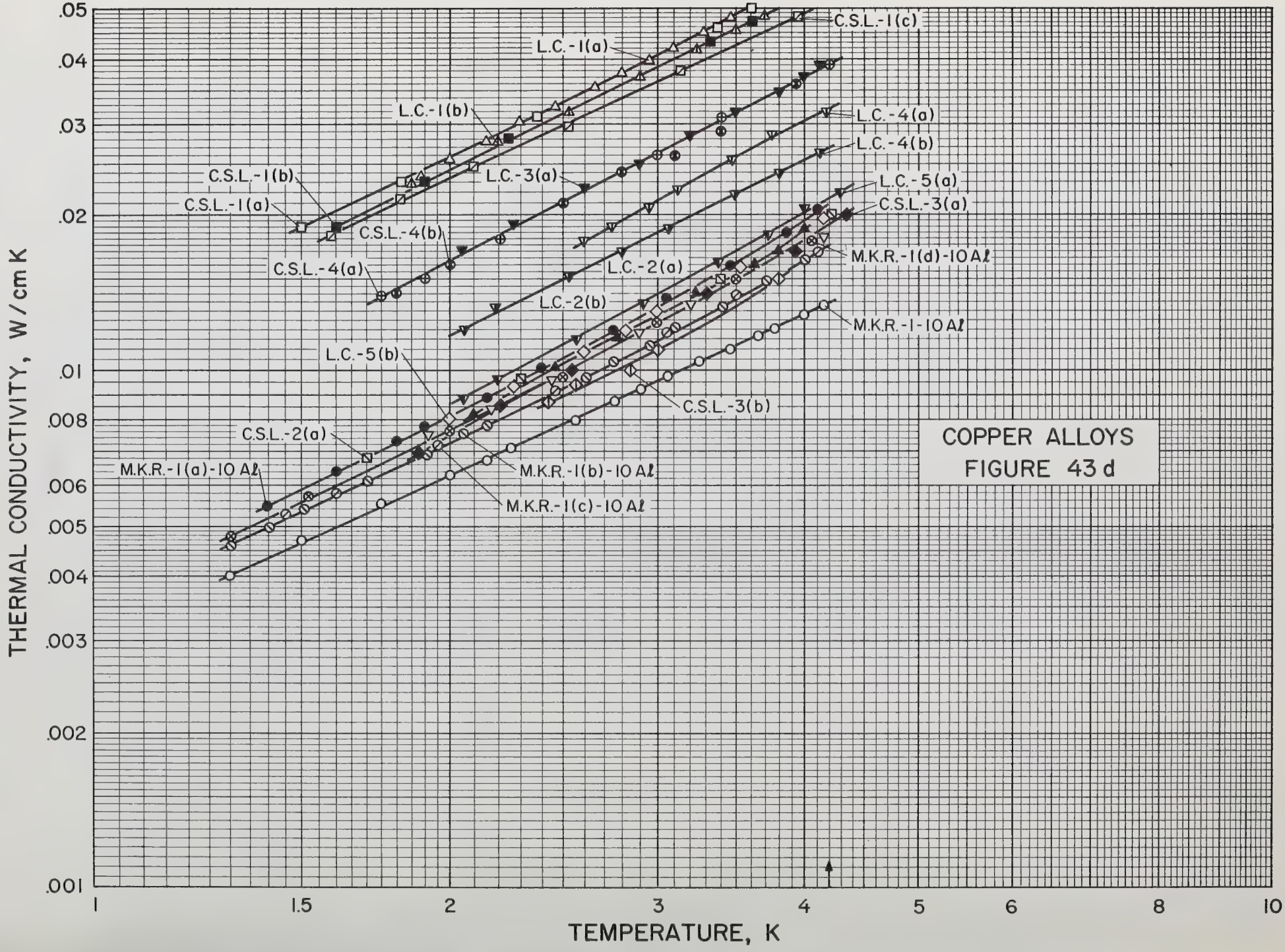
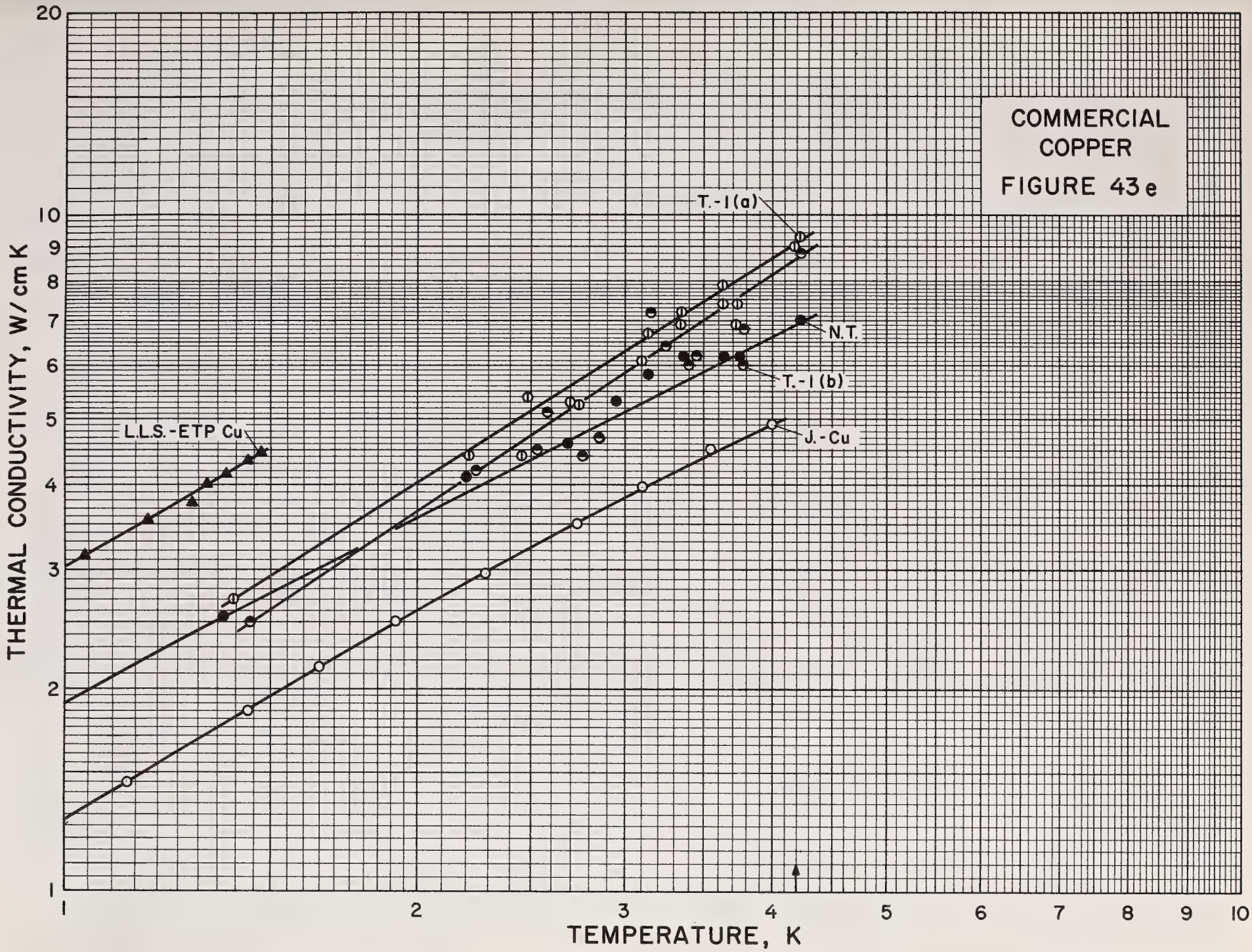
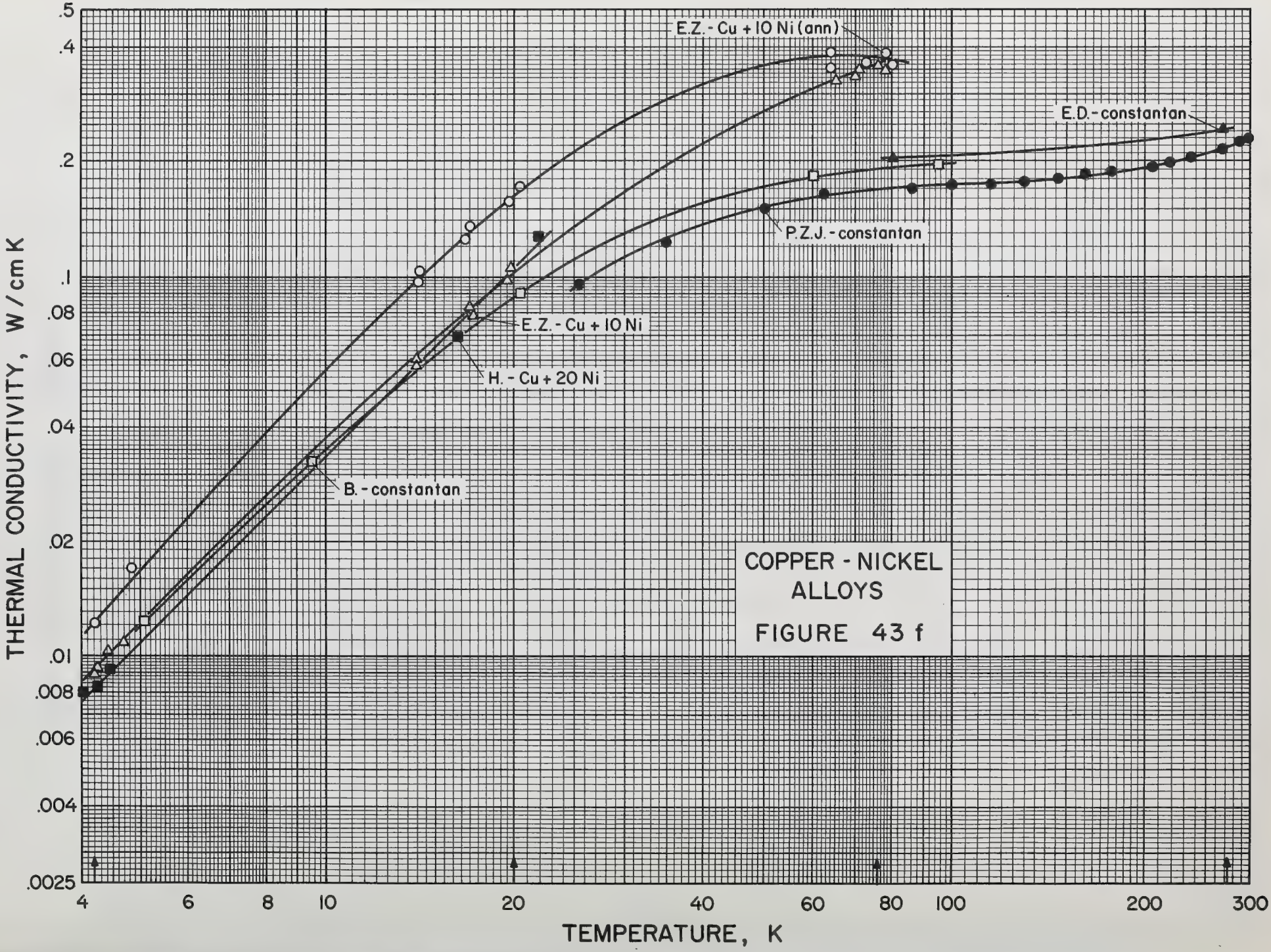

COPPER ALLOYS
FIGURE 43 a
THERMAL CONDUCTIVITY, W / cm K
TEMPERATURE, K
1.2
1.0
.8
.6
.4
.2
.1
.08
.06
.04
.02
.01
.008
.006
4
6
8
10
20
40
80
100
200
300
K.K.T.-10 Zn
L.- Brass
S.- 5 In
S.- 10 In
G.R.- 45 Pd (ann.)
G.R.- 25 Au (ann.)
G.R.-50 Au
G.R.-4 Au
G.R.- 10 Au
Z.Z.- P-Bronze
L.- Ger. silver
G.R.- 25 Au
G.R.- 6 Pd
K.K.T.-32 Zn(2)
K.S.- Ger. silver
L.- Plat.
L.- Manganin
G.R.-50 Pd
K.K.T.-32 Zn(1)
E.D.-1 (30 Mn)
Z.Z.- Manganin
E.D.- 2 (30 Mn)
G.R.- 45 Pd
K.S.- Bronze
B.- Ger. silver


THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
P.R.R.-Cu (coalesced)
P.R.R.-ETP Cu
P.R.C.-Cu (coalesced, ann.)
W.W.-Cu+Ge
P.C.-Leaded Cu
W.W.-1
P.S.J.-Cu
K.K.T.-2 Zn
S.C.S.-1.96 Zn
Z.Z.-Cu (ann)
W.W.-2
G.S.B.-Cu+In
P.R.R.-(Te) Cu
Z.Z.-Cu
S.C.S.-4.76 Zn
K.K.T.-Cu-As (ann.)
K.K.T.-7.5 Au
P.R.R.-2
K.K.T.-5 Zn
Z.Z.-Kupaloi
K.K.T.-16.5 Au
P.P.R.-P.D. Cu
G.V.R.K.-Cu3Au
P.R.R.-1
Z.Z.-German silver (ann.)
Z.Z.-German silver
COMMERCIAL COPPERS
and
COPPER ALLOYS
FIGURE 43 b


COMMERCIAL COPPERS
and COPPER ALLOYS
FIGURE 43 c
THERMAL CONDUCTIVITY, W / cm K
TEMPERATURE, K
1.0
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
.01
.008
.006
.004
.003
.002
.001
1
1.5
2
3
4
5
6
7
8
9
10
N.C. - 1 (b)
N.C. - 1 (a)
N.C. - 2
O. - 1
O. - 4
O. - 3
O. - 2
C.S. - 2.09 Al
C.S. - 6.10 Al
C.S. - 11.25 Al
S. - Bronze + P
A.M. - German Silver
H. - Cu + 20 Ni
G.V.R.K. - Cu3 Au
K.S. - 15 Al (1)
K.S. - 15 Al (2)
B. - German Silver
L.R. - 15 Zn
L.R. - 15 Zn (strain)


THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
.05
.04
.03
.02
.01
.008
.006
.005
.004
.003
.002
.001
1
1.5
2
3
4
5
6
8
10
C.S.L.-1(c)
L.C.-1(a)
L.C.-1(b)
C.S.L.-1(b)
C.S.L.-1(a)
C.S.L.-4(b)
C.S.L.-4(a)
L.C.-3(a)
L.C.-4(a)
L.C.-4(b)
L.C.-5(a)
C.S.L.-3(a)
M.K.R.-1(d)-10Al
L.C.-2(a)
L.C.-2(b)
M.K.R.-1-10Al
L.C.-5(b)
C.S.L.-3(b)
C.S.L.-2(a)
M.K.R.-1(a)-10Al
M.K.R.-1(b)-10Al
M.K.R.-1(c)-10Al
COPPER ALLOYS
FIGURE 43 d


COMMERCIAL COPPER
FIGURE 43e
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
T.-1(a)
N.T.
T.-1(b)
J.-Cu
L.L.S.-ETP Cu
20
10
9
8
7
6
5
4
3
2
1
1
2
3
4
5
6
7
8
9
10


E.Z. - Cu + 10 Ni (ann)
E.D. - constantan
P.Z.J. - constantan
E.Z. - Cu + 10 Ni
H. - Cu + 20 Ni
B. - constantan
COPPER - NICKEL ALLOYS
FIGURE 43 f
THERMAL CONDUCTIVITY, W / cm K
TEMPERATURE, K
.5
.4
.2
.1
.08
.06
.04
.02
.01
.008
.006
.004
.0025
4
6
8
10
20
40
60
80
100
200
300

COPPER ALLOYS
(See FIGURES 43a-43d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
		See also the "COPPER-NICKEL ALLOYS" and the "COMMERCIAL COPPERS" TABLES and FIGURES.		
. . . . .	#1: (~ 62 Cu, 22 Zn, 15 Ni). #2: (~ 82 Cu, 18 Zn). #3: (~ 65 Cu, 35 Zn).	#1: "Neusilber"; k = 0.29 at 0°C. #2: "red brass"; k = 1.03 at 0°C. #3: "yellow brass"; k = 0.85 at 0°C.	A-5; B-1; C-1; D-7(9); F-5; G-3; S-1, 3, 5.	L. Lorenz (1881b).
. . . . .	#1: 0.34 P. #2: 0.87 P. #3: 1.79 P. #4: 2.08 P. #5: 2.35 P. #6: 5.25 P. #7: 1.04 As. #8: 1.80 As. #9: 2.66 As. #10: 3.00 As. #11: 5.02 As.	#1: k = 0.95 at 15°C. #2: k = 0.61 at 15°C. #3: k = 0.53 at 15°C. #4: k = 0.34 at 15°C. #5: k = 0.27 at 15°C. #6: k = 0.15 at 15°C. #7: k = 1.14 at 15°C. #8: k = 0.82 at 15°C. #9: k = 0.54 at 15°C. #10: k = 0.54 at 15°C. #11: k = 0.20 at 15°C.	A-6; B-1; C-2; D-1(1); G-3.	A. Rietzsch (1900).
. . . . .	#1: 85.7 Cu, 7.15 Zn, 6.39 Sn, 0.58 Ni; #2: 84 Cu, 12 Mn, 4 Ni.	#1: "red brass"; k = 0.60 at 18°C; specific density of 8.40. #2: "manganin"; k = 0.22; specific density of 8.44.	A-4; B-1; C-2, 3; D-1(3); E-1; F-4; G-3; S-1, 2, 3, 5.	W. Jaeger and H. Diesselhorst (1900).
L.-Brass, Ger. Silver, Plat., Manganin	Brass: 70 Cu, 30 Zn. Ger. Silver: Johnson, Matthey; 62 Cu, 22 Zn, 15 Ni. Plat.: London Electric Wire Co.; approx. same as Ger. Silver. Manganin: Glover; 84 Cu, 12 Mn, 4 Ni.	Brass: specific density of 8.44 at 22°C. Ger. Silver: "german silver"; specific density of 8.67 at 22°C. Plat.: "platinoid"; specific density of 8.66 at 22°C. Manganin: "manganine"; specific density of 8.42 at 22°C.	A-1; B-1; C-1; D-2(2); E-2; F-4; G-3; L-1; S-1, 5.	C.H. Lees (1908).

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COPPER ALLOYS (cont'd)

(See FIGURES 43a-43d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Prepared from Kahlbaum copper, Merck zinc, and A.B. Nordiska Affineriet Helsingborg Au. #1: 7.1 (atomic) Zn. #2: 14.0 Zn. #3: 27.3 Zn. #4: 32.4 Zn. #5: 68.1 Cu, 31.9 Au. #6: 79.3 Cu, 20.7 Au. #7: 89.6 Cu, 10.4 Au.	Rolled and drawn; heated $\frac{1}{2}$ hr. close to melting pt. #1: k = 1.80 at 273 K. #2: k = 1.84 at 273 K. #3: k = 1.14 at 273 K. #4: k = 1.08 at 273 K. #5: k = 0.55 at 273 K. #6: k = 0.64 at 273 K. #7: k = 0.91 at 273 K.	A-4; B-1; C-3; D-1(2); F-4; G-3; M-2; S-1.	E. Sedström (1919).
. . . . .	. . . . . . #1: 1.8 (atomic) Au. #2: 4.4 Au. #3: 10.9 Au. #4: 20.9 Au. #5: 25.0 Au. #6: 27.4 Au. #7: 30.0 Au. #8: 35.1 Au. #9: 39.8 Au. #10: 45.0 Au.	Rolled and drawn; heated close to melting point. #1: k = 2.37 at 273 K. #2: k = 1.71 at 273 K. #3: k = 0.91 at 273 K. #4: k = 0.62 at 273 K. #5: k = 0.59 at 273 K. #6: k = 0.52 at 273 K. #7: k = 0.53 at 273 K. #8: k = 0.48 at 273 K. #9: k = 0.47 at 273 K. #10: k = 0.62 at 273 K.	Same as above.	E. Sedström (1924).
. . . . .	82 Cu, 18 Zn.	Measured effect of the apparent effect of grain size.	. . . . .	A. Eucken and O. Neumann (1924).
E.D.-1(30 Mn), 2(30 Mn)	Heraeus: 70 Cu, 30 Mn.	#1: ~ 48 grain boundaries/cm. #2: ~ 112 grain boundaries/cm. Two other specimens also measured, with intermediate results.	A-1; B-1; C-1; D-1(2); F-4; G-3; M-2; P-1, 4; S-1, 5.	A. Eucken and K. Dittrich (1927).
. . . . .	#1 and #2: 3 Ag.	#1: unannealed; k = 3.57 at 83 and 21 K. #2: annealed 3 hrs. at 390°C; k = 4.06 at 83 K; k = 6.19 at 21 K.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-3; L-1, 2; M-1; P-1; S-1, 5.	E. Grüneisen and E. Goens (1927).

COPPER ALLOYS (cont'd)

(See FIGURES 43a-43d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
G.R.-4 Au, 10 Au, 25 Au, 25 Au (ann), 50 Au, 50 Pd, 6 Pd, 45 Pd, 45 Pd (ann)	4 Au: 95.5 Cu, 4.5 Au. 10 Au: Degussa; 90.3 Cu, 9.7 Au. 25 Au: Degussa; 75.1 Cu, 24.9 Au. 25 Au(ann): same as 25 Au. 50 Au: Degussa; 49.9 Cu, 50.1 Au. 50 Pd: Siebert; 49.9 Cu, 50.1 Pd. 6 Pd: Heraeus; 93.6 Cu, 6.4 Pd. 45 Pd: Siebert; 55 Cu, 45 Pd. 45 Pd (ann): same as 45 Pd.	4 Au and 10 Au: polycrystalline; unannealed. 25 Au: specimen first quenched from 800°C, k = 0.34 at 83K; then annealed 20 hrs. at 400°C, k = 0.61 at 83K; then annealed 32 hrs. at 360°C, k = 0.63 at 83K; then annealed 2 hrs. at 820°C and quenched, k = 0.23 at 83K; then annealed 5 months at room temperature, curve shown. 25 Au (ann): same as 25 Au, then further annealed 30 hrs. at 320°C. 50 Au: annealed 30 hrs. at 320°C. 50 Pd: annealed. 6 Pd: polycrystalline; unannealed. 45 Pd: specimen first annealed, k = 0.67 at 83K; then annealed 2 hrs. at 800°C, curve shown. 45 Pd (ann): same as 45 Pd, then further annealed 30 hrs. at 320°C.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-3; L-1; M-2; P-1; S-1.	E. Grüneisen and H. Reddemann (1934).
. . . . .		Values determined at 20°C. Sometimes the composition percentages add up to more than 100. The copper-silicon alloys were hot-rolled, cold-drawn, and annealed at 700°C; homogeneous α-solid solution.	A-1; B-1; C-1, 2; D-1(3); F-1; G-3; M-2; S-1, 5.	C.S. Smith and E. W. Palmer (1935).
	99.986(weight) Cu, 0.0016 Fe, 0.02 O_2, 0.0015 S.	k = 3.93.		
	99.80 Cu, 0.19 Si, 0.02 Fe.	k = 2.13.		
	99.78 Cu, 0.23 Si, 0.02 Fe.	k = 1.92.		
	99.65 Cu, 0.32 Si, 0.032 Fe.	k = 1.65.		
	99.53 Cu, 0.45 Si, 0.03 Fe.	k = 1.29.		
	99.06 Cu, 1.00 Si, 0.03 Fe.	k = 0.82.		
	98.09 Cu, 1.98 Si, 0.05 Fe.	k = 0.51.		
	96.00 Cu, 3.91 Si, 0.02 Fe.	k = 0.34.		

COPPER ALLOYS (cont'd)

(See FIGURES 43a-43d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	The miscellaneous alloys were extensively worked, annealed, and slowly cooled except where noted.	A-1; B-1; C-1, 2; D-1(3); F-1; G-3; M-2; S-1, 5.	C.S. Smith and E. W. Palmer (1935).
	99.986 Cu, 0.002 Fe, 0.02 O_2.	k = 3.94.		
	96.24 Cu, 33.72 Zn, 0.03 Pb, 0.01 Fe, 0.001 S.	k = 1.20.		
	96.94 Cu, 3.04 Zn, 0.02 Fe.	k = 2.68.		
	95.21 Cu, 4.77 Zn, 0.02 Fe.	k = 2.42.		
	97.49 Cu, 0.06 Fe, 0.27 Ni, 2.24 Be.	Quenched, k = 0.86; reheated, k = 1.03; quenched, cold-drawn, k = 0174; reheated, k = 0.82.		
	85.10 Cu, 12.97 Zn, 1.88 Pb, 0.05 Fe.	k = 1.60.		
	61.85 Cu, 34.79 Zn, 3.29 Pb, 0.07 Fe.	k = 1.08.		
	65.99 Cu, 29.18 Zn, 4.02 Pb, 0.01 Fe.	k = 1.11.		
	88.07 Cu, 3.70 Zn, 3.77 Sn, 3.83 Pb, 0.03 Fe.	k = 0.90.		
	88.08 Cu, 4.09 Zn, 3.76 Sn, 3.80 Pb, 0.02 Fe, 0.25 P.	k = 0.56.		
	60.41 Cu, 37.09 Zn, 1.03 Sn, 1.12 Pb, 0.02 Fe, 0.18 Al, 0.21 Si.	Chill-cast, k = 1.00.		
	56.01 Cu, 25.93 Zn, 17.95 Ni, 0.18 Mn, 0.08 Fe, 0.02 C.	k = 0.30.		
	63.76 Cu, 19.79 Zn, 16.29 Ni, 0.18 Mn, 0.14 Fe.	k = 0.34.		
	65.51 Cu, 23.86 Zn, 10.36 Ni, 0.18 Mn, 0.08 Fe, 0.01 C.	k = 0.46.		
	59.76 Cu, 29.88 Zn, 10.13 Ni, 0.15 Mn, 0.04 Fe, 0.04 Mg.	k = 0.42.		
	64.04 Cu, 30.50 Zn, 5.41 Ni, 0.05 Fe.	k = 0.59.		
	56.57 Cu, 17.65 Zn, 13.24 Ni, 10.44 Pb, 2.23 Sn, 0.10 Fe.	Sand-cast, k = 0.31.		
	89.08 Cu, 5.11 Al, 4.98 Ni, 0.74 Si, 0.08 Fe.	Quenched, k = 0.45; reheated, k = 0.57; furnace-cooled, k = 0.66.		

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COPPER ALLOYS (cont'd)

(See FIGURES 43a-43d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
	56.13 Cu, 42.34 Zn, 1.02 Ni, 0.49 Fe.	k = 1.14.	A-1; B-1; C-1,2; D-1(3); F-1; G-3; M-2; S-1,5.	C.S. Smith and E. W. Palmer (1935).
	89.38 Cu, 9.41 Al, 0.52 Fe, 0.38 Sn, 0.31 Ni.	k = 0.60.		
	75.79 Cu, 22.22 Zn, 1.98 Al, 0.01 Fe.	k = 1.00.		
	59.35 Cu, 38.36 Zn, 1.06 Fe, 0.98 Sn, 0.13 Pb, 0.12 Mn.	k = 1.01.		
	99.654 Cu, 0.32 Si, 0.03 Fe.	k = 1.65.		
	95.61 Cu, 4.51 Mn, 0.11 Fe.	k = 0.46.		
	99.21 Cu, 0.85 Cd, 0.01 Fe and Si.	k = 3.45.		
	98.41 Cu, 1.07 Cd, 0.59 Sn, 0.02 Fe and Si.	k = 2.33.		
	72.49 Cu, 17.76 Zn, 4.44 Al, 3.34 Mn, 1.78 Fe.	k = 0.50.		
	94.00 Cu, 4.68 Si, 1.03 Mn, 0.08 Fe.	Sand-cast, k = 0.25		
	95.69 Cu, 3.23 Si, 0.99 Mn, 0.16 Fe.	k = 0.33.		
	98.10 Cu, 1.50 Si, 0.30 Mn, 0.06 Fe.	k = 0.54.		
	81.55 Cu, 14.21 Zn, 4.00 Si, 0.20 Mn, 0.04 Fe.	Chill-cast, k = 0.28		
	95.83 Cu, 3.11 Si, 1.12 Zn, 0.02 Fe.	k = 0.37.		
	78.30 Cu, 13.32 Pb, 8.04 Sn, 0.20 Ni, 0.1 P.	Sand-cast, k = 0.42.		
	87.86 Cu, 8.87 Sn, 3.05 Zn, 0.03 Fe.	Sand-cast, k = 0.54.		
	88.36 Cu, 9.55 Sn, 1.90 Zn, 0.07 Fe.	Sand-cast, k = 0.50.		
	60.54 Cu, 36.46 Zn, 1.48 Sn, 0.73 Fe, 0.21 Mn, 0.04 Al.	Sand-cast, k = 0.96.		
	99.04 Cu, 0.9 Cd, 0.07 Fe.	k = 2.76.		
	50.75 Cu, 48.69 Fe, 0.47 Mn, 0.05 Si, 0.02 C.	k = 0.99.		

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COPPER ALLOYS (cont'd)

(See FIGURES 43a-43d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	The copper-aluminum alloys were rolled and annealed at 700°C and were in the α-solid solution (except the 12.15% Al, which was δ).	A-1; B-1; C-1,2; D-1(3); F-1, G-3; M-2; S-1,5.	C.S. Smith and E. W. Palmer (1935).
	99.95 Cu, 0.07 Al, 0.01 Fe.	k = 3.52.		
	99.77 Cu, 0.22 Al, 0.01 Fe.	k = 2.91.		
	99.47 Cu, 0.47 Al, 0.02 Fe.	k = 2.35.		
	99.20 Cu, 0.71 Al, 0.09 Fe.	k = 1.75.		
	98.08 Cu, 1.89 Al, 0.03 Fe.	k = 1.23.		
	95.25 Cu, 4.61 Al, 0.14 Fe.	k = 0.83.		
	92.15 Cu, 7.72 Al, 0.13 Fe.	k = 0.72.		
	90.56 Cu, 9.37 Al, 0.07 Fe.	k = 0.65.		
	89.88 Cu, 9.90 Al, 0.22 Fe.	k = 0.66.		
	87.76 Cu, 12,15 Al, 0.09 Fe.	k = 0.54.		
. . . . .	. . . . .	The copper-manganese alloys were deoxidized with magnesium, hot-rolled, and annealed at 700°C.	Same as above.	Same as above.
	99.94 Cu, 0.07 Mn, 0.01 Fe, 0.02 Mg.	k = 3.62.		
	99.88 Cu, 0.14 Mn, 0.01 Fe, 0.01 Mg.	k = 3.28.		
	99.55 Cu, 0.43 Mn. 0.01 Fe, 0.01 Mg.	k = 2.26.		
	99.05 Cu, 1.05 Mn, 0.01 Fe, 0.01 Mg.	k = 1.50.		
	98.27 Cu, 1.77 Mn, 0.03 Fe, 0.01 Mg.	k = 1.02.		
	95.34 Cu, 4.55 Mn, 0.06 Fe, 0.02 Mg.	k = 0.49.		
	90.25 Cu, 9.53 Mn, 0.18 Fe, 0.02 Mg, 0.021 C.	k = 0.26.		
	80.03 Cu, 19.82 Mn, 0.09 Fe, 0.02 Mg, 0.035 C.	k = 0.15.		

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COPPER ALLOYS (cont'd)

(See FIGURES 43a-43d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	See COPPER-NICKEL ALLOYS Table.	. . . . .	M. Cook (1936).
K.S.-Ger. silver, Bronze	Ger. silver: Injekta A.-G.; 64 Cu, 20 Zn, 16 Ni. Bronze: Cochius; 46 Cu, 41 Zn, 13 Ni.	Ger. silver: "neusilber". Bronze: "silber-bronze".	A-1; B-1; C-1; D-1(2); E-4, 5; F-4; G-3; M-1; S-1, 5.	J. Karweil and K. Schäfer (1939).
A.M.-Ger. silver	45.9 Cu, 42.1 Zn, 9.8 Ni, 2.0 Pb, 0.15 Fe, 0.05 Mn; RRR = 6.	"German silver"; machined nearly to size, annealed in air, final light cut taken.	A-1; B-1; C-1; D-2(2); E-5; F-4; G-2; M-1; P-1; S-1, 5.	J.F. Allen and E. Mendoza (1947).
B.-Ger. silver	Rollets; 47 Cu, 41 Zn, 9 Ni, 2 Pb; RRR(17) = 1.15.	Grain size mean diameter of 0.02 mm. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-3, 4(2); E-4; F-4; G-2; L-1; M-1; O-3; P-2, 4; Q-1; S-1.	R. Berman (1951 b).
S.-Bronze + P	Phosphor bronze.	. . . . .	A-4; B-1; C-3; D-2; E-5; G-3; S-1.	R.A. Chentsov (1954).
P.C.-Leaded Cu	98.94 Cu, 1.04 Pb.	Free-machined; Cu grains ~ 40μ in the transverse section and ~ 80μ long by 40μ wide in the longitudinal section; Knoop hardness (with a 1 kg load) ~ 121 in transverse section and ~ 127 in longitudinal section.	A-1; B-1; C-1; D-1(8); E-2; F-3; G-1; L-1; M-1.	R.L. Powell and C.O. Coffin (1955).
Z.Z.-P-Bronze, Manganin	P-Bronze: 93.3 Cu, 6.46 Sn, 0.20 P. Manganin: 85 Cu, 12 Mn, 3 Ni.	P-Bronze and Manganin: not tempered. See also COMMERCIAL COPPERS Table.	A-1; B-1; C-1; D-3(2); E-3, 5; G-3; L-1; M-1.	N.V. Zavaritskii and A.C. Zeldovich (1956).
P.R.R.-1, 2	#1: 3.15 Si, 1.13 Mn, 1 Zn, 0.001 Ag, Cd, Cr, and Fe, < 0.001 Al, B, Ca, Pb, and Sn. #2: 35.7 Zn, 3.27 Pb, 1 Sn, 0.01 Ag, Bi, Cd, Fe, and Ni, 0.001 In, Sb, and Si, < 0.001 Al and As, < 0.0001 Co and Mg.	#1: silicon bronze, type A; turned and ground from a hard temper rod; Brinell hardness of 215 on longitudinal axis and 218 on transverse axis. #2: free-cutting leaded brass; ground down; hard temper for maximum machinability; two phase alpha-beta system; Brinell hardness of 191 on longitudinal axis and 186 on transverse axis; average grain size of 0.024 × 0.01 mm along longitudinal axis, 0.012 × 0.012 mm along transverse axis; density of 8.468 g/cm^3. See also COMMERCIAL COPPERS Table.	A-1; B-1; C-1; D-1(8); E-2; F-3; G-2; L-1, 2; M-2, 4.	R.L. Powell, H.M. Roder, and W.M. Rogers (1957).

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COPPER ALLOYS (cont'd)

(See FIGURES 43a-43d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
K.K.T.-2 Zn, 5 Zn, 10 Zn, 7.5 Au, 16.5 Au	Garrett, Davidson, and Matthey 2 Zn: RRR(20) = 4.1; 98 Cu, 2 Zn. 5 Zn: RRR(20) = 2.50; 95 Cu, 5 Zn 10 Zn: RRR(20) = 2.00; 90 Cu, 10 Zn. 7.5 Au: RRR(20) = 1.52; 92.5 Cu, 7.5 Au. 16.5 Au: RRR(20) = 1.26; 83.5 Cu, 16.5 Au.	2 Zn, 5 Zn, 10 Zn: drawn, annealed 4 hrs. at 85°C while enclosed in closely fitting sheaths of same material. 7.5 Au and 16.5 Au: annealed 1 hr. at 750°C. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-4(2); E-2, 5; F-4; G-2; L-1, 2; M-2; P-2, 3, 8; Q-1; S-1, 5.	W.R.G. Kemp, P. G. Klemens, and R.J. Tainsh (1957), see also Kemp, Klemens, Tainsh, and G. K. White (1957).
. . . . .	#1: 88 Cu, 5.7 Sn, 1.4 Pb, 4.4 Zn, 0.07 Fe, 0.13 Sb, 0.6 Ni, 0.01 P. #2: 79 Cu, 9.3 Sn, 10.2 Pb, 0.27 Zn, 0.01 Fe, 0.26 Sb, 0.43 Ni, 0.01 P. #3: 85 Cu, 4.4 Sn, 5.1 Pb, 4.6 Zn, 0.11 Fe, 0.17 Sb, 0.7 Ni, 0.01 P.	Trade designations - #1: Navy "M". #2: 80-10-10. #3: 85-5-5-5. Ingot alloys designated as 2A, 3A, and 4A, respectively, by ASTM Specification B30-54. Cast in sand molds; specifications are ASTM B143-52, B144-52, and B62-52, respectively. k = 0.70, 0.48, and 0.72, respectively, at 20°C.	A6; B-1; C-1; D-1(5); F-1; G-3; S-1, 6.	J.G. Kura and R. M. Lang (1958).
L.R.-15 Zn, 15 Zn(strain)	Prepared from Johnson, Matthey spectrographically standardized materials; 85 Cu, 15 Zn.	α-brass. Melted and shaken together in quartz tubes in vacuum; swaged. 15 Zn(strain): after initial measurement, specimen strained at room temperature in a Hounsfield Tensometer by amount 19.8%. Intermediate strains of 4.6 and 10.4% resulted in intermediate values.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1; M-1; P-3, 6, 9; Q-1.	J.N. Lomer and H.M. Rosenberg (1959).
K.K.T.-32 Zn (1), 32 Zn(2)	32 Zn: ~ 32 Zn. #(1): RRR(20) = 1.42. #(2): RRR(20) = 1.48.	Alpha-brass. Thick rod, annealed at 700°C, deformed torsionally ($nd/\ell = 1.88$), specimens cut and machined; #(1): annealed at 250°C; #(2): annealed at temperature increasing at 6°/min up to 400°C. Two others also measured: one deformed with results 8% lower than #(1) at high temperatures and the same at low temperatures; the other annealed at 290°C with results 8% greater than #(1) at high temperatures and the same at low temperatures. Graph of lattice thermal conductivity. See also COMMERCIAL COPPERS Table.	A-1; B-1; C-1; D-4(2); E-2, 5; F-4; G-2; L-1, 2; O-3; P-2, 3, 6, 9; Q-1; S-1.	W.R.G. Kemp, P. G. Klemens, and R.J. Tainsh (1959b); see also Kemp and Klemens (1960), and Kemp, Klemens, Tainsh, and G. K. White (1957).

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COPPER ALLOYS (cont'd)

(See FIGURES 43a-43d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
O.-1, 2, 3, 4	#1: 95.40(weight) Cu, 0.01 Pb, balance Zn. #2: 86.56 Cu, 0.01 Fe, balance Zn. #3: 84.53 Cu, 0.02 Fe and Pb, balance Zn. #4: 69.95 Cu, 0.02 Fe, 0.01 Pb, balance Zn.	Machined. #1: annealed in air 21 hrs. at 540°C. #2: before machining subjected to considerable amount of cold work, annealed in air 17 hrs. at 500°C. #3 and #4: annealed in air 21 hrs. at 540°C. Another specimen of intermediate composition also measured.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-3; L-1; M-2; O-9; P-2, 3; Q-1; S-1, 5.	T. Olsen (1959).
. . . . .	. . . . .	Graphs of lattice thermal conductivity between 1 and 5 K and phonon mean-free-path for copper alloys with impurities of Ge, Al, Ga, or In less than 4% concentration.	. . . . .	P. Lindenfeld and W.B. Pennebaker (1962).
. . . . .	. . . . .	Graphs of lattice thermal conductivity between 0.35 and 4.2 K of single phase copper alloys with impurities of Ge less than 8% concentration.	. . . . .	D.S. McLachlan (1963).
. . . . .	#1: American Smelting and Refining; Cu + 6 Ge. #2: Cu-Sn.	Graph of lattice thermal conductivity.	. . . . .	M.H. Jericho (1965).
C.S.-2.09 Al, 6.10 Al, 11.25 Al	International Research and Development; prepared from O.F.H.C. Cu and spectroscopically pure Al.	Melted and stirred in graphite crucible in high purity argon atmosphere; cast into ingots in a graphite mold; machined, swaged, and drawn; annealed in vacuum at least 14 hrs. at 750°C, furnace-cooled. Grain size of 0.1 to 0.3 mm. Measurements on 3 other specimens with intermediate compositions gave intermediate values.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-2; M-2; O-5, 9; P-2, 3, 5; Q-1.	P. Charsley and J.A.M. Salter (1965).
. . . . .	. . . . .	Graphs of reduced lattice thermal conductivity of Cu alloys of composition 2 to 7.5% Ge between 0.35 and 4 K.	. . . . .	P. Lindenfeld, E. A. Lynton, D.S. McLachlan, and R. Soulen (1966).

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COPPER ALLOYS (cont'd)

(See FIGURES 43a-43d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	Graph of lattice thermal conductivity as a function of temperature and as a function of deformation for Cu + 4.6%(atomic) Ga.	. . . . .	R. Zeyfang (1967).
C.S.L.-1(a), 1(b), 1(c), 2(a), 3(a), 3(b), 4(a), 4(b)	International Research and Development Co. #1(a)-#1(c): Cu+2(atomic) Al. #2(a): Cu + 8 Al. #3(a) and #3(b): Cu + 12 Al. #4(a) and #4(b): α-brass.	#1-#3: melted and stirred in graphite crucible in argon atmosphere, then cast in graphite. #4: induction melted in argon in a drop cast furnace; sv aged and drawn. All specimens then annealed in vacuum at 750°C for 15 hrs, furnace cooled. Grains about 0.1 mm diameter. #1(a) and #4(a): not deformed. Others deformed in tension at room temperature with a strain rate of 2×10^{-3}/sec. Deformed by: #1(b)-2.9%; #1(c)-10%; #2(a)-6%; #3(a)-6.2%; #3(b)-12.8%; #4(b)-4.4%.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-2; M-2; P-3, 4, 9; Q-1.	P. Charsley, J. A. M. Salter, and A. D. W. Leaver (1968).
G.V.R.K.-Cu_3 Au	Prepared from ASARCO 99.999 Cu and Au; 0.1 Fe impurity as a substitute for Cu; RRR (27) = 1.23.	Cu_3Au: disordered. Melted in vacuum in quartz tubes, homogenized by rocking; cast; machined; annealed 2 hrs. at 850°C; quenched from 700°C in water; fcc structure of disordered phase. Graphs of electronic and lattice thermal conductivity.	A-1; B-1; C-1; D-1, 3(2); E-4, 5; F-4; G-2; L-1; M-2; O-2, 3, 5; P-2, 3, 5; Q-2; S-1, 5.	J.F. Goff, A.C. Verbalis, J.J. Rhyne, and P.G. Klemens (1969).
S.C.S.-1.96 Zn, 4.76 Zn	Prepared from Johnson, Matthey spectroscopically pure rods of Cu and Zn.	Sealed in evacuated quartz tube, heated to 1100°C; melted and thoroughly shaken; cooled to 900°C, and held 5 days at 900°C; rolled; annealed in evacuated sealed glass tubes for 6 hrs. at 500°C. Graphs and tables of electronic and lattice thermal conductivity.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-3; L-1; O-2, 3; P-2; S-1.	B.N. Srivastava, S. Chatterjee, and S.K. Sen (1969).
K.S.-15 Al(1), 15 Al(2)	Prepared from Mitsubishi-Kinzoku Co. 99.999 pure Cu and Sumitomo-Kinzoku Co. 99.99 pure Al; 15 Al.	Single crystals. Materials melted in high-purity graphite crucible by induction heating; single crystals grown by Bridgman method; cut chemically; annealed 48 hrs. under vacuum at about 1000°C; electrolytically polished. Dislocation densities of: #(1) 1.0×10^6; #(2) 8.4×10^{10}/cm^2. #1: no deformation. #2: deformation of 29.0 kg/mm^2 and 0.61 elongation. Five other specimens of intermediate dislocation densities and deformations also measured, with intermediate results. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-2; L-1; O-5; P-3, 9; Q-1; S-1.	M. Kusunoki and H. Suzuki (1969).

COPPER ALLOYS (cont'd)
(See FIGURES 43a–43d)

CURVE	SAMPLE SOURCE COMPOSITION	REMARKS	CODE	REFERENCE
S. -5In, 10In	Prepared from Johnson, Matthey spectrographically pure rods of copper and indium.	Melted in vacuum in quartz tube at 1100°C, shaken in molten condition; reduced to 850-900°C, annealed for 11 days, rolled and reannealed at 500°C for several hours. Also measured Cu + 2% In specimen with results 10% greater than G. S. B. -Cu+In curve on FIGURE 43b.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-3; L-1; M-1; O-2, 3, 9; Q-1; S-1.	B. N. Srivastava, S. Chatterjee, S. K. Sen, and D. K. Chakraborty (1970).
M. K. R. -1, 1(a), 1(b), 1(c), 1(d)-10Aℓ	Materials Research Corp.; Cu + 10(atomic) Aℓ; prepared from 99.999 Cu and Aℓ.	Prepared by vacuum induction melting; machined, swaged; stored in liquid nitrogen. #1: as received. #1(a): specimen #1 annealed at 1193 K for 48 hrs. Specimen then annealed at 1123 K for 28 hrs and given 9.5% torsional strain at 293 K before the following anneals and remeasurements. #1(b): annealed at 300 K for 12 hrs. #1(c): annealed at 373 K for 48 hrs. #1(d); annealed at 713 K for 48 hrs. Twenty other experimental runs were also reported. Graphs of lattice conductivity.	A-1; B-1; C-1; D-3(2); E-5; G-2; M-2, 3; N-7; P-3; Q-1; S-1, 5.	M. A. Mitchell, P. G. Klemens, and C. A. Reynolds (1971).
L. C. -1(a), 2(a), 2(b), 3(a), 4(a), 4(b), 5(a), 5(b)	International Research and Development Co. #1: Cu + 1.93(atomic) Aℓ. #2: Cu + 12.18 Aℓ. #3: Cu + 27.2 Zn. #4: Cu + 9.9 Au. #5: Cu + 12.18 Aℓ.	Prepared as were specimens C.S.L. -1. #5: single crystals. All but #1(a), 2(a), 4(a), and 5(a) were deformed in tension at room temperature with strain rate 2×10^{-3} S^{-1}. Specimens deformed as follows: #1(b)-8.2%; #2(b)-18%; #3(a)-3.2%; #4(b)-13.4%. #5(b) was measured at beginning of stage III of deformation. Two other Cu + 12 Aℓ were measured at stage I and II deformation, with results between #5(a) and #5(b).	A-1; B-1; C-1; D-3(2); E-5; F-4; G-2; M-2; P-3, 4, 7, 9; Q-1; S-1.	A. D. W. Leaver and P. Charsley (1971).

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COPPER ALLOYS (cont'd)

(See FIGURES 43a-43d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
		All values below are at room temperature. Copper-zinc, brass, and Zinc-bronze.		
. . . . .	70.0-73.0 Cu, 0.9-1.2 Sn, 0.02-0.10 As, P, or Sb, 0.07 Pb, 0.06 Fe, balance Zn.	Admiralty Metal (inhibited); equivalent to ASTM B111, B43, and B171, and British B.S. 378, 885, 886 and 1464; k = 1.1.	. . . . .	Alloy Digest (1952-68).
. . . . .	76.0-79.0 Cu, 1.8-2.5 Al, 0.07 Pb, 0.06 Fe, 0.02-0.10 As, P, or Sb, balance Zn.	Aluminum Brass; equivalent to ASTM B111; k = 1.0.	. . . . .	Same as above.
. . . . .	Balance Cu, 13.5-14.5 Zn, 4.2-5.2 Si, 0.5 others total.	Aur-O-Met 145; k = 0.030.	. . . . .	Same as above.
. . . . .	56.0-59.0 Cu, 2.5-4.0 Mn, 2.0-4.0 Al, 1.25-2.5 Fe, 0.5 other elements, balance Zn.	Bohnolloy R-57; k = 0.50.	. . . . .	Same as above.
. . . . .	76.0-79.0 Cu, 1.8-2.5 Al, 0.07 Pb, 0.06 Fe, 0.02-0.10 As, balance Zn.	Bridgeport 54; equivalent to ASTM B111 and B395; k = 1.0.	. . . . .	Same as above.
. . . . .	68.5-71.5 Cu, 0.07 Pb, 0.06 Fe, 0.02-0.10 Hg, balance Zn.	Bridgeport Alloy 77; equivalent to B111; k = 1.2.	. . . . .	Same as above.
. . . . .	68.5-71.5 Cu, 0.07 Pb, 0.05 Fe, balance Zn.	Cartridge Brass, 70%; equivalent to ASTM B14, 19, B36#6, B134#6, and B135#2, and SAE 70A, 74C, and 80A; k = 1.2.	. . . . .	Same as above.
. . . . .	60.50 Cu, 38.75 Zn, 0.75 Sn.	Chamet Bronze Type A; equivalent to AMS 4611B and 4612C, ASTM B21 alloy A and B124 alloy 3, and SAE73; k = 1.2.	. . . . .	Same as above.

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COPPER ALLOYS (cont'd)

(See FIGURES 43a-43d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	89.0-91.0 Cu, 0.05 Fe and Pb, balance Zn.	Commercial Bronze, 90%; equivalent to ASTM B36#2, B130, B134#2, Revere Alloy No. 2; k = 1.9.	. . . . .	Alloy Digest (1952-68).
. . . . .	89.00 Cu, 8.95 Zn, 1.90 Sn, 0.15 P.	Contact Bronze; k = 1.3.	. . . . .	Same as above.
. . . . .	58.0-61.0 Cu, 1.5-2.5 Pb, 0.30 Fe, balance Zn.	Copper Alloy No. 377; equivalent to MIL-B-895, ASTM B124 alloy 2, and SAE88; k = 1.2.	. . . . .	Same as above.
. . . . .	55.0-60.0 Cu, 2.00-3.8 Pb, 0.35 Fe, balance Zn.	Copper Alloy No. 385; k = 1.2.	. . . . .	Same as above.
. . . . .	60.0-63.0 Cu, 2.50-3.70 Pb, 0.15 Fe, balance Zn.	Free-cutting Brass; equivalent to AMS 4610, ASTM B16, and SAE 72; k = 1.2.	. . . . .	Same as above.
. . . . .	94.0-96.0 Cu, 0.05 Fe, 0.03 Pb, balance Zn.	Gilding Brass, 95%; equivalent to ASTM B36#1 and B134#1; k = 2.3.	. . . . .	Same as above.
. . . . .	60.00-68.00 Cu, 3.00-7.50 Al, 2.50-5.00 Mn, 2.00-4.00 Fe, balance Zn.	Hy-Ten-Sl No. 1; k = 0.59.	. . . . .	Same as above.
. . . . .	59.0-62.0 Cu, 1.3-2.2 Pb, 0.5-1.0 Sn, 0.01 Fe, balance Zn.	Leaded Naval Brass; equivalent to ASTM B21 alloy C; k = 1.2.	. . . . .	Same as above.
. . . . .	59.0-62.0 Cu, 0.5-1.0 Sn, 0.4-1.0 Pb, balance Zn.	Leaded Naval Brass-605; equivalent to ASTM B21 alloy B; k = 1.2.	. . . . .	Same as above.
. . . . .	78.5-81.5 Cu, 0.05 Fe and Pb, balance Zn.	LOW Brass, 80%; equivalent to ASTM B36 No. 4 and B134 No. 4; k = 1.4.	. . . . .	Same as above.
. . . . .	57.75 Cu, 40.0 Zn, 1.00 Al and Fe, 0.25 Mn.	Lumen Alloy 9; equivalent to AMS 4860A, ASTM B142-52-8A, and SAE 43; k = 1.1.	. . . . .	Same as above.

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COPPER ALLOYS (cont'd)

(See FIGURES 43a-43d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	57.0-60.0 Cu, 0.8-2.0 Fe, 0.5-1.5 Sn, 0.25 Al, 0.20 Pb, 0.05-0.5 Mn, balance Zn.	Manganese Bronze; equivalent to AMS 4860, ASTM B147 alloy 8A, and SAE 43; wrought, k = 1.1.	. . . . .	Alloy Digest (1952-68).
. . . . .	59.00-63.00 Cu, 0.30 Pb, 0.07 Fe, balance Zn.	Muntz Metal; equivalent to AMS 4555, ASTM B43, B111, B124, and B135 No.5, and SAE 74; k = 1.23.	. . . . .	Same as above.
. . . . .	59.0-62.0 Cu, 0.5-1.0 Sn, 0.20 Pb, 0.10 Fe, balance Zn.	Naval Brass; equivalent to AMS 4611B and 4612C, ASTM B21-A, B124 No.3, and B171, and SAE 73; k = 1.16.	. . . . .	Same as above.
. . . . .	84.0-86.0 Cu, 0.06 Pb, 0.05 Fe, balance Zn.	Red Brass, 85%; equivalent to ASTM B36#3, B134#3, B111, B135#1, SAE 74D and 79A; k = 1.6.	. . . . .	Same as above.
. . . . .	78.5-81.5 Cu, 0.05 Fe and Pb, balance Zn.	Revere No.140; equivalent to ASTM B36 and B134 No.4 and SAE 79B; k = 1.4.	. . . . .	Same as above.
. . . . .	60.00-63.00 Cu, 2.50-3.70 Pb, 0.35 Fe, balance Zn.	Revere No.240; k = 1.1.	. . . . .	Same as above.
. . . . .	89.0-91.0 Cu, 0.3-0.7 Sn, balance Zn.	Revere Alloy 411; k = 1.7.	. . . . .	Same as above.
. . . . .	57.0-60.0 Cu, 0.8-2.0 Fe, 0.5-1.5 Sn, 0.05-0.5 Mn, balance Zn.	Revere No.454; equivalent to AMS 4619, ASTM B138 alloy A and B124 alloy 4; k = 1.1.	. . . . .	Same as above.
. . . . .	95.00 Cu, 4.00 Zn, 1.00 Sn.	Riverside No.105; equivalent to CABRA No.405; k = 1.80.	. . . . .	Same as above.
. . . . .	59.0-62.0 Cu, 0.5-1.0 Sn, 0.20 Pb, 0.10 Fe and other impurities, balance Zn.	Scobronze; equivalent to ASTM B21-A and B124 No.3, SAE 73, and British B.S.409, 1541, 251, and 252; k = 1.2.	. . . . .	Same as above.

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COPPER ALLOYS (cont'd)

(See FIGURES 43a-43d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	60.00 Cu, 39.25 Zn, 0.75 Sn.	Tobin Bronze 452; equivalent to AMS 4611B and 4612C, ASTM B121 alloy A and B124 alloy No. 3, and SAE 73; k = 1.2.	. . . . .	Alloy Digest (1952-68).
. . . . .	Balance Cu, 12.0-15.0 Zn, 3.0-5.0 Si.	Tombasil; equivalent to ASTM B30 alloy 13B, B176 alloy ZS 144A, and B198 alloy 13B; k = 0.022.	. . . . .	Same as above.
. . . . .	64.0-68.5 Cu, 0.15 Pb, 0.05 Fe, balance Zn.	Yellow Brass; equivalent to ASTM B134#7 and B138#8; k = 1.2.	. . . . .	Same as above.
		Copper-tin and tin-bronze.		
. . . . .	94 Cu, 3.5-5.8 Sn, 0.30 Zn, 0.10 Fe, 0.05 Pb, 0.03-0.35 P, 0.01 Sb.	Phosphor Bronze Alloy A; equivalent to AMS 4510, 4520, 4625, and 4720, ASTM B103, B139, B159, and B100, and SAE 77, 81, and 791; k = 0.81.	. . . . .	Same as above.
. . . . .	90.5 Cu, 7.0-9.0 Sn, 0.20 Zn, 0.10 Fe, 0.05 Pb, 0.03-0.35 P, 0.01 Sb.	Phosphor Bronze Alloy C; equivalent to same as Alloy A above; k = 0.62.	. . . . .	Same as above.
. . . . .	88.5 Cu, 9.0-11.0 Sn, 0.20 Zn, 0.10 Fe, 0.05 Pb, 0.03-0.25 P, 0.01 Sb.	Phosphor Bronze Alloy D; equivalent to same as Alloy A above; k = 0.50.	. . . . .	Same as above.
. . . . .	98.5 Cu, 1.0-1.5 Sn, trace P.	Phosphor Bronze Alloy E; equivalent to same as Alloy A above; k = 2.1.	. . . . .	Same as above.
. . . . .	88.5 Cu, 9.0-11.0 Sn, 0.20 Zn, 0.10 Fe, 0.05 Pb, 0.01 Sb, 0.03-0.25 P.	Seymour No. 910; equivalent to ASTM B103, B139, and B159 alloy D; k = 0.50.	. . . . .	Same as above.
. . . . .	> 90.5 Cu, 7.0-9.0 Sn, 0.20 Zn, 0.10 Fe, 0.05 Pb, 0.03-0.35 P, 0.01 Sb.	Seymour No. 928; ASTM B103, B159, B139 alloy C and SAE 77; k = 0.62.	. . . . .	Same as above.
. . . . .	94.85 Cu, 5.0 Sn, 0.15 P.	Seymour No. 950; equivalent to ASTM B103-A, B139-A, B159-A, and SAE 77 and 81; k = 0.73.	. . . . .	Same as above.

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COPPER ALLOYS (cont'd)

(See FIGURES 43a-43d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Balance Cu, 4.5-5.5 Sn, 0.8-1.2 Pb, 0.03-0.15 P.	Seymour No. 9494; equivalent to ASTM B103 and B139 Gr. B-1; k = 0.81.	. . . . .	Alloy Digest (1952-68).
. . . . .	> 96.7 Cu, 1.00 Zn, 0.90-1.25 Ni, 0.40-0.60 Te, 0.15-0.25 P, 0.10 Fe and Pb.	Telnic Bronze; k = 2.11.	. . . . .	Same as above.
		Copper-aluminum and aluminum-bronze.		
. . . . .	92-96 Cu, 4-7 Al.	Ambraloy-901; equivalent to ASTM B169 and B111; k = 0.78.	. . . . .	Same as above.
. . . . .	90.0-93.0 Cu, 7.0-9.0 Al.	Ambraloy-928; equivalent to AMS 4630D and 4632B, ASTM B124, B150, B169, and B225, and SAE 701B; k = 0.69.	. . . . .	Same as above.
. . . . .	Balance Cu, 6.00-8.00 Al, 1.50-3.00 Fe, 0.50 other elements.	Ampco Metal-8; equivalent to ASTM B169 alloy D and MIL-B-15939 comp. 5; k = 0.75.	. . . . .	Same as above.
. . . . .	Balance Cu, 8.0-9.5 Al, 2.25-3.25 Fe, 0.50 other elements.	Ampco Metal-12; equivalent to ASTM B148 Alloy 9A; SAE-68A Grade A cast, and MIL-B-16033 class 1; k = 0.80.	. . . . .	Same as above.
. . . . .	Balance Cu, 8.5-10.0 Al, 2.50-3.75 Fe, 0.50 other elements.	Ampco 15; equivalent to ASTM B150 alloy 1, MIL-B-6946, and SAE 7018; k = 0.75.	. . . . .	Same as above.
. . . . .	Balance Cu, 9.30-10.30 Al, 2.75-4.0 Fe, 0.50 other elements.	Ampco Metal-16; k = 0.81.	. . . . .	Same as above.
. . . . .	Balance Cu, 10.00-12.00 Al, 3.00-4.25 Fe, 0.50 other elements.	Ampco Metal-18; equivalent to AMS 4635B, and ASTM B148 alloy 9C; k = 0.75.	. . . . .	Same as above.
. . . . .	Balance Cu, 11.00-12.20 Al, 3.25-4.50 Fe, 0.50 other elements.	Ampco Metal-20; k = 0.71.	. . . . .	Same as above.

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COPPER ALLOYS (cont'd)

(See FIGURES 43a-43d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Balance Cu, 12.5-13.6 Al, 3.5-5.0 Fe, 0.50 others.	Ampco Metal-21; k = 0.67.	. . . . .	Alloy Digest (1952-68).
. . . . .	Balance Cu, 13.60-14.60 Al, 4.00-5.25 Fe, 0.50 others.	Ampco 22; k = 0.67.	. . . . .	Same as above.
. . . . .	Balance Cu, 8.5-9.8 Al, 0.3-1.0 Fe and Ni, 0.25-0.60 Sn, 0.5 other elements.	Avialite-915; equivalent to AMS 4630-E and 4632-C, ASTM B124 alloy 11A and B150 alloy 1, and SAE 701B; k = 0.61.	. . . . .	Same as above.
. . . . .	Balance Cu, 2.75-4.25 Al, 0.75-1.25 Si.	Bridgeport 712; k = 0.57.	. . . . .	Same as above.
. . . . .	90.78 Cu, 7.15 Al, 2.00 Si, 0.07 As.	Duronze 707; equivalent to AMS 4631C, ASTM B124 alloy 11a and B150 alloy 1, and SAE 701B; k = 0.38.	. . . . .	Same as above.
. . . . .	89 Cu, 6.5-8.0 Al, 1.5-3.0 Si.	Everdur-1014; equivalent to ASTM B150 alloy No.1, B124 alloy 11a, and B283, and SAE 701B; k = 0.451.	. . . . .	Same as above.
. . . . .	87.0 Cu, 9.5-10.5 Al, 0.75-1.5 Fe.	Lumen Alloy 11-C; equivalent to ASTM B148 Gr.9B and SAE 68 Gr.B; k = 0.88.	. . . . .	Same as above.
. . . . .	62.0-66.0 Cu, 5.0-7.5 Al, 2.5-4.5 Mn, 2.0-4.0 Fe, balance Zn.	Lumen Alloy 20; equivalent to AMS 4862B, ASTM B147-52-8C, and SAE 430B; k = 0.88.	. . . . .	Same as above.
. . . . .	Balance Cu, 11 Al, 4 Fe.	Lumen 97; k = 0.71.	. . . . .	Same as above.
. . . . .	> 86 Cu, 9.00-11.00 Al, 0.75-1.50 Fe.	Resistac No.1; k = 0.88.	. . . . .	Same as above.
. . . . .	Balance Cu, 4.0-6.0 Al, 0.025-0.045 As.	Revere No.429; equivalent to ASTM B111 and B124; k = 0.83.	. . . . .	Same as above.
. . . . .	Balance Cu, 7.0 Al, 2.25 Fe.	Revere No.430; equivalent to ASTM B169, B124, and B150; k = 0.80.	. . . . .	Same as above.

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COPPER ALLOYS (cont'd)

(See FIGURES 43a-43d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Balance Cu, 8.0-10.0 Al, 2.0-4.0 Fe.	Tuf-Stuf 224C; equivalent to AMS 4635B, ASTM B124 alloy 11a, and SAE 701B; k = 0.61.	. . . . .	Alloy Digest (1952-68).
. . . . .	Balance Cu, 8.50-9.50 Al, 0.70-1.50 Fe.	Tuf-Stuf 224E-30; equivalent to AMS 4630, ASTM B124 alloy 11a and B150 alloy 1, and SAE 701B; k = 0.61.	. . . . .	Same as above.
. . . . .	Balance Cu, 9.00-10.00 Al, 0.70-1.50 Fe.	Tuf-Stuf 224E-75; equivalent to AMS 4630 and 4632, ASTM B124 alloy 11a and B150 alloy 1, and SAE 701B; k = 0.61.	. . . . .	Same as above.
. . . . .	86-87 Cu, 10.5-11.5 Al, 2-3 Fe.	Tuf-Stuf 224H; equivalent to AMS 4635 and ASTM B148 alloy 9C; k = 0.05.	. . . . .	Same as above.
. . . . .	Balance Cu, 12.5-13.6 Al, 3.5-5.0 Fe, 0.5 other elements.	Wearite 4-13; k = 0.67.	. . . . .	Same as above.
		Miscellaneous copper alloys.		
. . . . .	Balance Cu, 3.5-4.5 Pb and Sn, 1.5-4.5 Zn, 0.03-0.15 P.	Chase 444 Bronze; equivalent to ASTM 139 alloy B2 and SAE 791; k = 0.81.	. . . . .	Same as above.
. . . . .	Balance Cu, 2.8-3.8 Si, 1.5 Mn.	Duronze 606; equivalent to ASTM B96, B97, B98, and B99 alloy A; k = 0.36.	. . . . .	Same as above.
. . . . .	98.1 Cu, 1.9 Si.	Duronze 609; equivalent to ASTM B97, B98, and B99 alloy B; k = 0.47.	. . . . .	Same as above.
. . . . .	Balance Cu, 2.8-3.8 Si, 1.6 Fe.	Duronze 632; equivalent to ASTM B97 alloy A; k = 0.36.	. . . . .	Same as above.
. . . . .	95.8 Cu, 3.1 Si, 1.1 Mn.	Everdur-655; k = 0.33.	. . . . .	Same as above.
. . . . .	95.8 Cu, 3.1 Si, 1.1 Mn.	Everdur-1010; k = 0.33.	. . . . .	Same as above.

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COPPER ALLOYS (cont'd)

(See FIGURES 43a-43d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	> 96.0 Cu, 1.25-1.75 Si, 0.25 Fe, 0.10-0.50 Mn, 0.05 Pb.	Everdur-1015; equivalent to ASTM B97 alloy B-12, B98 alloy B12, and B99 alloy B12, and MIL-C-17516 comp. No. 2; k = 0.54.	. . . . .	Alloy Digest (1952-68).
. . . . .	Balance Cu, 2.80-3.25 Si, 0.75-1.25 Mn.	Herculoy 420; k = 0.36.	. . . . .	Same as above.
. . . . .	Remainder Cu, 1.50-2.00 Si, 0.15-0.40 Mn.	Herculoy 421; equivalent to ASTM B97, B98, B99, B105, and B124; k = 0.57.	. . . . .	Same as above.
. . . . .	Balance Cu, 2.5 Co, 0.5 Be.	Mallory 100; forged, k = 2.0; cast, k = 2.0.	. . . . .	Same as above.
. . . . .	90.0 Cu, 2.4-4.0 Si, 1.5-4.0 Fe and Zn, 1.0 Mn, 0.1 P.	Mueller 803; k = 0.33.	. . . . .	Same as above.
. . . . .	58.0-61.0 Cu, 1.5-2.5 Pb, 0.15-0.25 Sn.	Noranda-3770; equivalent to MIL-B-895, ASTM B124 alloy 2, and SAE 88; k = 1.2.	. . . . .	Same as above.
. . . . .	97.3-97.8 Cu, 2.1-2.6 Fe, 0.01-0.03 P.	Olin No. 605; k = 2.44.	. . . . .	Same as above.
. . . . .	87.5 Cu, 12.5 Zn.	Jewelry Bronze, 87.5%; k = 1.7.	. . . . .	Metals Handbook (1961).
. . . . .	89 Cu, 9.25 Zn, 1.75 Pb.	Leaded Commercial Bronze; equivalent to ASTM B140 alloy B; k = 1.8.	. . . . .	Same as above.
. . . . .	66 Cu, 33.5 Zn, 0.5 Pb.	Low-Leaded Brass (tube); equivalent to ASTM B135 alloy 3; k = 1.2.	. . . . .	Same as above.
. . . . .	65 Cu, 34 Zn, 1 Pb.	Medium-Leaded Brass; equivalent to ASTM B121 alloy 3; k = 1.2.	. . . . .	Same as above.
. . . . .	66 Cu, 32.4 Zn, 1.6 Pb.	High-Leaded Brass (tube); equivalent to ASTM B135 alloy 4; k = 1.2.	. . . . .	Same as above.
. . . . .	65 Cu, 33 Zn, 2 Pb.	High-Leaded Brass; equivalent to ASTM B121 alloy 5; k = 1.2.	. . . . .	Same as above.

COPPER ALLOYS (cont'd)

(See FIGURES 43a-43d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	63 Cu, 34.5 Zn, 2.5 Pb.	Extra-High-Leaded Brass; equivalent to ASTM B121 alloy 6; k = 1.2.	. . . . .	Metals Handbook (1961).
. . . . .	60 Cu, 39.4 Zn, 0.6 Pb.	Leaded Muntz Metal; equivalent to ASTM B171; k = 1.2.	. . . . .	Same as above.
. . . . .	59 Cu, 39 Zn, 2 Pb.	Forging Brass; equivalent to ASTM B124 alloy 2; k = 1.2.	. . . . .	Same as above.
. . . . .	57 Cu, 40 Zn, 3 Pb.	Architectural Bronze; k = 1.2.	. . . . .	Same as above.
. . . . .	71 Cu, 28 Zn, 1 Sn.	Inhibited Admiralty; equivalent to ASTM B171; k = 1.1.	. . . . .	Same as above.
. . . . .	88 Cu, 4 Pb, 4 Sn, 4 Zn.	Free-Cutting Phosphor Bronze; equivalent to ASTM B139 alloy B2; k = 0.75.	. . . . .	Same as above.
. . . . .	96 Cu, 3 Si.	High-Silicon Bronze (A); equivalent to ASTM B97 alloy A; k = 0.38.	. . . . .	Same as above.
. . . . .	97.7 Cu, 1.5 Si.	Low-Silicon Bronze, Type B; equivalent to ASTM B97 alloy B; k = 0.58.	. . . . .	Same as above.
. . . . .	95 Cu, 5 Al.	Aluminum Bronze, 5% Al; equivalent to ASTM B169 alloy A; k = 0.83.	. . . . .	Same as above.
. . . . .	91 Cu, 7 Al, 2 Fe.	Aluminum Bronze (3); equivalent to ASTM B150 alloy 3; k = 0.75.	. . . . .	Same as above.
. . . . .	91 Cu, 7 Al, 2 Si.	Aluminum-Silicon Bronze; equivalent to ASTM B124 alloy 11a; k = 0.45.	. . . . .	Same as above.
. . . . .	91 Cu, 9 Al.	Aluminum Bonze (1); equivalent to ASTM B150 alloy 1; k = 0.60.	. . . . .	Same as above.
. . . . .	97.9 Cu, 1.9 Be, 0.2 Ni or Co.	Beryllium Copper; ASTM B194, B196, or B197; cold work, k = 0.59-0.71; precipitation hardened, k = 0.84-1.2.	. . . . .	Same as above.

COPPER ALLOYS (cont'd)
(See FIGURES 43a–43d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
		All values listed below are at or near room temperature, unless otherwise noted.		
. . . . .	3-5 Al, 3-5 Mn, 0.2 C, 0.04 N_2, 150 ppm H_2.	MST 4 Al-4 Mn; k = 81 mW/cm-K.	. . . . .	Alloy Digest (1952-68).
. . . . .	3.75-4.75 Al, 2.5-3.5 Mo, 0.75-1.25 V, 0.25 Fe, 0.15 H_2, 0.08 C, 0.05 N_2.	Ti-4Al-3Mo-1V; MST 431; Crucible C-115 A Mo V; Republic RS-115; k = 67 mW/cm-K.	. . . . .	Same as above.
. . . . .	4 Al, 4 Mn, 0.05 C.	Rem-Cru C-130 AM; k = 81 mW/cm-K.	. . . . .	Same as above.
. . . . .	4 Al, 4 Mn, 0.3 Fe, 0.1 C, 0.018 N_2, 0.0125 H_2.	Republic RS-130; k = 69 mW/cm-K.	. . . . .	Same as above.
. . . . .	4-6 Al, 1.5-3.5 Sn.	MST 5 Al - 2.5 Sn; k = 75 mW/cm-K at 273 K.	. . . . .	Same as above.
. . . . .	4-6 Al, 2-3 Sn, 0.5 Fe, 0.08 C, 0.5 N_2, 0.0175 H_2.	Ti-5 Al - 2.5 Sn; k = 75 at 273 K.	. . . . .	Same as above.
. . . . .	4.25-5.25 Al, 2-3 Sn, 0.45 Fe, 0.2 O_2, 0.05 C, 0.02 N_2, 0.0175 H_2 (sheet), 0.015 H_2 (bar).	ASTM-B-265 Gr. 6; ASTM-B-348; Republic RS-110C; k = 75 at 273 K.	. . . . .	Same as above.
. . . . .	5 Al, 2.5 Sn.	Rem-Cru A-110 AT; k = 67 mW/cm-K at 200 K; k = 75 mW/cm-K at 273 K.	. . . . .	Same as above.
. . . . .	5-6 Al, 1.1-1.7 Cr and Fe, 0.9-1.5 Mo, 0.08 C, 0.05 N_2, 0.0125 H_2.	Ti-155A; k = 83 mW/cm-K.	. . . . .	Same as above.
. . . . .	5-6 Al, 5-6 V, 1.5-2.5 Sn, 0.35-1.0 Cu and Fe, 0.2 O_2, 0.05 C, 0.04 N_2, 0.015 H_2.	Ti-6AR-6V-2Sn; k = 73 mW/cm-K.	. . . . .	Same as above.
. . . . .	5.5-6.5 Al, 3.5-4.5 V, 0.1 C, 0.03 N_2.	Rem-Cru C-120 AV; k = 66 mW/cm-K.	. . . . .	Same as above.
. . . . .	6.3-7.3 Al, 3.5-4.5 Mo, 0.15 C, 0.07 N_2, 0.0125 H_2.	Rem-Cru C-135 AMo; k = 64 mW/cm-K.	. . . . .	Same as above.
. . . . .	6.5-7.5 Al, 3.5-4.5 Mo, 0.15 C and Fe, 0.07 N_2, 0.0125 H_2.	Ti-7Al-4Mo; MST 7Al-4Mo; Crucible C-135 AMO; Republic RS-135; k = 64 mW/cm-K.	. . . . .	Same as above.
. . . . .	6.5-7.5 Al, 3.5-4.5 Mo, 0.2 O_2, 0.08 C, 0.05 N_2, 0.0125 H_2.	Harvey HA-7146; k = 64 mW/cm-K.	. . . . .	Same as above.

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COPPER ALLOYS (cont'd)
(See FIGURES 43a–43d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	7.5-8.5 Aℓ, 0.75-1.25 Mo and V, 0.3 Fe, 0.08 C, 0.05 N_2, 0.015 H_2.	Ti-8Aℓ-1Mo-1V; k = 60 mW/cm-K.	. . . . .	Alloy Digest (1952-68).
. . . . .	0.10 C, 0.07 N_2, 0.015 H_2 (sheet), 0.0125 H_2(bar), 0.01 H_2(billet).	Crucible A-40; k = 200 mW/cm-K.	. . . . .	Same as above.
. . . . .	0.15 C, 0.07 N_2, 0.015 H_2.	Rem-Cru A-70; k = 173 mW/cm-K.	. . . . .	Same as above.
. . . . .	0.20 C, 0.08 N_2, 0.015 H_2.	Rem-Cru A-55; k = 200 mW/cm-K.	. . . . .	Same as above.
. . . . .	0.2 Fe, 0.15-0.2 Pd, 0.08 C, 0.05 N_2, 0.015 H_2(sheet), 0.0125 H_2(bar), 0.010 H_2 (billet).	Ti-0.15 Pd; k = 164 mW/cm-K.	. . . . .	Same as above.
. . . . .	2 Fe, 2 Cr, 2 Mo.	Ti-2Fe-2Cr-2Mo; k = 170 mW/cm-K.	. . . . .	Same as above.
. . . . .	7-9 Mn.	Rem-Cru C-110M; k = 110 mW/cm-K.	. . . . .	Same as above.
. . . . .	7.5 Mn, 0.2 Fe, 0.13 O_2, 0.04 C, 0.025 N_2.	MST 8 Mn; k = 109 mW/cm-K.	. . . . .	Same as above.
. . . . .	8 Mn.	Ti-8 Mn; k = 170 mW/cm-K.	. . . . .	Same as above.
. . . . .	8 Mn, 0.1 C, 0.05 N_2.	ASTM B265-58T-Gr. 7; Republic RS-110A; k = 109 mW/cm-K.	. . . . .	Same as above.
. . . . .	25 Ni, 13.2 C, 5 Mo, 4.5 Nb, 0.3 Ta.	Kentanium K162B; k = 355 mW/cm-K.	. . . . .	Same as above.
. . . . .	12.5-14.5 V, 10-12 Cr, 2-4 Aℓ.	Crucible B-120VCA; k = 64 mW/cm-K.	. . . . .	Same as above.
. . . . .	12.5-14.5 V, 10-12 Cr, 2.5-3.5 Aℓ, 0.08 N_2, 0.05 C, 250 ppm H_2.	Ti-13V-11Cr-3Aℓ; k = 69 mW/cm-K.	. . . . .	Same as above.

COMMERCIAL COPPERS
(See FIGURES 43b, 43c, and 43e)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
		Total additives ≤ 1%. See also the "COPPER ALLOYS" and the "COPPER-NICKEL ALLOYS" TABLES and FIGURES.		
. . . . .	0.34P.	k = 0.95 at 15°C. See also COPPER ALLOYS Table.	A-6; B-1; C-2; D-1(1); G-3.	A. Rietzsch (1900).
	0.87P.	k = 0.61 at 15°C.		
. . . . .	. . . . .	Values determined at 20°C. Sometimes the composition percentages add up to more than 100. See also COPPER ALLOYS TABLE. The copper-silicon alloys were hot-rolled, cold-drawn, and annealed 2 hrs. at 700°C; homogeneous α-solid solution.	A-1; B-1; C-1,2; D-1(3); F-1; G-3; M-2; S-1,5.	C. S. Smith and E. W. Palmer (1935).
	99.80 (weight) Cu, 0.19 Si, 0.02 Fe.	k = 2.13.		
	99.78 Cu, 0.23 Si, 0.02 Fe.	k = 1.92.		
	99.65 Cu, 0.32 Si, 0.032 Fe.	k = 1.65; "annealed only 1 hr.".		
	99.53 Cu, 0.45 Si, 0.03 Fe.	k = 1.29.		
	99.06 Cu, 1.00 Si, 0.03 Fe.	k = 0.82.		
. . . . .	. . . . .	The copper-aluminum alloys were rolled and annealed 2 hrs. at 750°C; α-solid solution.	Same as above.	Same as above.
	99.95 Cu, 0.07 Al, 0.01 Fe.	k = 3.52.		
	99.77 Cu, 0.22 Al, 0.01 Fe.	k = 2.91.		
	99.47 Cu, 0.47 Al, 0.02 Fe.	k = 2.35.		
	99.20 Cu, 0.71 Al, 0.09 Fe.	k = 1.75; "annealed at only 700°C".		
. . . . .	. . . . .	The copper-manganese alloys were deoxidized with magnesium, hot-rolled, annealed 2 hrs. at 700°C.	Same as above.	Same as above.
	99.94 Cu, 0.07 Mn, 0.01 Fe, 0.02 Mg.	k = 3.62.		
	99.88 Cu, 0.14 Mn, 0.01 Fe, 0.01 Mg.	k = 3.28.		
	99.55 Cu, 0.43 Mn, 0.01 Fe, and Mg.	k = 2.26.		
	99.05 Cu, 1.05 Mn, 0.01 Fe, and Mg.	k = 1.50.		

COMMERCIAL COPPERS (cont'd)

(See FIGURES 43b, 43c, and 43e)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	The miscellaneous alloys were extensively worked, annealed, and slowly cooled.	A-1; B-1; C-1, 2; D-1(3); F-1; G-3; M-2; S-1, 5.	C. S. Smith and E. W. Palmer (1935).
	99.986 Cu, 0.02 O_2, 0.0016 Fe.	k = 3.93; annealed 1 hr at 550°C.		
	99.654 Cu, 0.03 Fe, 0.32 Si	k = 1.65; annealed 1 hr at 700°C.		
	99.04 Cu, 0.9 Cd, 0.07 Fe.	k = 2.76; annealed 1-1/2 hr. at 750°C.		
	99.21 Cu, 0.85 Cd; 0.007 Fe, 0.009 Si.	k = 3.44; annealed 2 hrs at 700°C.		
P.S.J. -Cu	Am. Brass; "OFHC"	Oxygen-free, high conductivity.	A-1; B-1; C-1; D-1(2); E-1; F-2; G-2; L-1; M-1.	R. W. Powers, D. Schwartz, and H. L. Johnston (1951).
N.T.; also see FIGURE 71	General Electric; "commerical grade high-purity".	Magnet wire. Also measured below 1 K.	A-1; B-5; C-1; D-3(2); E-6; F-4; G-3; L-1; M-1.	J. Nicol and T. P. Tseng (1953).
T. -1(a), 1(b)	General Electric; "commercial grade purity".	Same specimen as N.T. above measured in two runs.	A-1; B-5; C-1; D-3(2), 6(2); E-6; F-4; G-3; L-1; M-1.	T. P. Tseng (1954).
W.W. -1, 2	#1: nominally 0.0043 (weight) Fe; RRR(22)=42. #2: nominally 0.056 Fe; RRR(22) = 3.1.	Homogenized and annealed. Graph of electronic and lattice thermal conductivity.	A-1; B-1; C-1; D-4(2); E-1, 5; F-4; G-2; L-1, 2; M-6; O-5; Q-1; S-1, 5.	G. K. White and S. B. Woods (1954); see also G. K. White and S. B. Woods(1955); see also G. K. White, S. B. Woods, and M. T. Elford (1959); see also G. K. White (1960).
W.W. -Cu+Ge	0.02 (weight) Ge; RRR(22) = 2.28.	Homogenized and annealed.	A-1; B-1; C-1; D-4(2); E-1, 5; F-4; G-2; L-1; M-1; S-1, 5.	G. K. White and S. B. Woods (1955).
P.C. -Leaded Cu	98.94 Cu, 1.04 Pb.	See COPPER ALLOYS Table.	. . . . .	R.L. Powell and D.O. Coffin (1955).

COMMERCIAL COPPERS (cont'd)

(See FIGURES 43b, 43c, and 43e)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
Z. Z. -Cu, Cu (ann), Kupaloi	Cu: brand M-3; 0.20 Ni, O.1 O_2, 0.05 As, Fe, Pb, Sb, and Sn, 0.01 S, 0.003 Bi, balance Cu. Cu(ann): same as Cu. Kupaloi: 99.2 Cu, 0.61 Cr, 0.18 Ag.	Cu: not tempered. Cu(ann): annealed to 800°C. Kupaloi: "hard Kupaloi". See also COPPER ALLOYS Table.	A-1; B-1, 4; C-1; D-3(2); E-3, 5; G-3; L-1; M-1; O-5.	N. V. Zavaritskii and A. C. Zeldovich (1956).
P. R. C. -Cu (coalesced) (ann)	"High purity commercial copper"; 13 ppm (weight) O_2, 8 ppm Pb, 7 ppm Ni, < 5 ppm As, Fe, and Sb, 2 ppm Sn, < 1 ppm Ag and Te, < 0.5 ppm Bi.	Annealed in helium 4 hrs. at 400°C, cooled slowly to 200°C; kept at 200°C for 8 hrs; kept in flowing helium atmosphere during entire heating cycle. Density of 8.90 g/cm^3; Vickers hardness (with 10 kg weight) of 54.1 longitudinal and 48.8 transverse, see also COPPER ALLOYS Table.	A-1; B-1; C-1; D-1(8); E-2; F-3; G-2.	R. L. Powell, W. M. Rogers, and D. O. Coffin (1957).
P. R. R. -ETP Cu, Cu (coalesced), (Te) Cu, P. D. Cu	DTP Cu: 0.01 (weight) Fe, 0.001 Ag and Zn, < 0.001 Aℓ, Cr, Mg, Mn, Pb, and Sn. Cu (coalesced): Same specimen as P. R. C. -Cu(coalesced)(ann) above, only unannealed. (Te)Cu: 0.56 Te, 0.007 P, 0.001 Ag, Fe, Si, and Zn, < 0.001 Aℓ, Mg, Mn, Pb, and Sn. P. D. Cu: 0.027 P, 0.01 Ag, Fe, and Zn, 0.001 Ni and Si, < 0.0001 Aℓ, Cr, Mg, Mn, and Pb.	ETP Cu: electrolytic tough pitch copper; controlled amounts of cuprous oxide, usually 0.02 to 0.05%, deliberately added during refining process; ground to size. Cu(coalesced): extruded, cold-rolled in ten passes, open-fire annealed 1 hr at 649°C, redrawn in two passes, annealed for 17 min at 760°C, ground to size; numerous small voids noticed, apparently reducing density by about 0.5%. (Te)Cu: free-cutting tellurium copper; ground to size; had commercial hard temper. P. D. Cu: phosphorus deoxidized copper; ground to size; had commercial hard temper. Respective densities of 8.914, 8.899, 8.909, 8.917 g/cm^3. Respective longitudinal average grain sizes: 0.088 x 0.024, 0.04 x 0.05, 0.1 x 0.016, 0.13 x 0.028 mm. Respective transverse average grain sizes: 0.02 x 0.02, 0.08 x 0.04, 0.016 x 0.016, 0.036 x 0.036 mm. Respective longitudinal x transverse Brinnell hardnesses: 124 x 123, 53.5 x 55, 133 x 130, 128 x 128. See also COPPER ALLOYS Table.	A-1; B-1; C-1; D-1(8); E-2; F-3; G-1; L-1, 2; M-2, 4; N-8; P-3; Q-1.	R. L. Powell, H. M. Roder, and W. M. Rogers (1957).

COMMERCIAL COPPERS (cont'd)
(See FIGURES 43b, 43c, and 43e)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
K. K. T. -Cu + As(ann)	99.55 Cu, 0.35 As, 0.05 P; RRR(20) = 1.46.	Drawn; prolonged anneal at 450°C; torsionally deformed; annealed to 450°C in helium atmosphere at rate of 6°/min increase. Graph of lattice thermal conductivity. Control specimen measured after first anneal; values same as Cu+As(ann) at lowest temperatures and 3% greater than Cu + As(ann) between 5 and 95 K. Another specimen measured before last anneal; values same as Cu + As(ann) at lowest temperatures and 10% less than Cu + As(ann) at higher temperatures. See also COPPER ALLOYS Table.	A-1; B-1; C-1; D-4(2); E-2, 5; F-4; G-2; L-1, 2; O-3; P-2, 3, 6, 9; Q-1; S-1.	W. R. G. Kemp, P. G. Klemens, and R. J. Tainsh (1959b); see also W. R. G. Kemp and P. G. Klemens (1960).
. . . . .	. . . . .	ETP Copper: measurements at 84 K, k = 5.63; at 97 K, k = 5.12; at 105 K, k = 4.88; at 109 K, k = 4.86.	A-1; B-1; C-1; D-1(8); E-2; F-2; G-2; L-1.	C. F. Smith (1963).
G. S. B-Cu + In	Prepared from American Smelting and Refining 99.999 Cu, and solute metals from Jarrell-Ash and Consolidated Mining of >99.99 purity; 0.76 (atomic) In, 0.23 Cd; RRR(20) = 1.62.	Constituents etched, rinsed, dried; melted in vacuum or inert atmosphere by induction heating; poured into cool copper mold; homogenized 6 days at 600°C; swaged; annealed 3 hrs at 600°C. Graph of electronic and lattice thermal conductivities for Cu + Sn, Cu + Cd + In, Cu + Zn + In, and Cu + Zn + Ga alloys.	A-1; B-1; C-1; D-1(2); E-2; F-4; G-2; L-1; O-2, 3; P-2, 3.	M. Garber, B. W. Scott, and F. J. Blatt (1963).
J. -Cu; also see FIGURE 71	Cu wire; RRR ≅ 85.	Also measured below 1 K.	A-1; B-5; C-1; D-3(2); E-4, 5; F-4; G-2; M-1; S-1.	M. H. Jericho (1965).
L. L. S. -ETP Cu also see FIGURE 71	Chase Brass and Copper; RRR = 270.	Annealed 3 hrs at 530°C. Also measured below 1 K.	A-1; B-5; D-3; E-3, 5, 6; G-2; M-1.	P. Lindenfeld, E. A. Lynton, and R. Soulen (1965).
. . . . .	. . . . .	Measured heat conduction of sintered copper sponge between 4.2 and 300 K.	. . . . .	D. O. Edwards (1966).

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COMMERCIAL COPPERS (cont'd)
(See FIGURES 43b, 43c, and 43e)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
N. C. -1(a), 1(b), 2	Prepared from Johnson, Matthey pure copper and pure manganese. #1: 0.11 (atomic) Mn. #2: 0.30 Mn.	Prepared in vacuum in quartz tubes; considered strained. #1(a) and #2: measured in zero magnetic field. #1(b): measured in transverse magnetic field of 1.74 T. Specimen with 0.21 (atomic) Mn also measured, with intermediate results. Specimen #1 measured in transverse magnetic fields of 1.04 and 1.375T with intermediate results. Specimens #2 and of 0.21 Mn also measured in transverse magnetic field of 1.74T, with results 15% greater than when in zero magnetic field. Graph of electronic and lattice thermal conductivity. All values below are at room temperature.	A-1; B-1; C-1; D-3(2); G-2; M-1, 2; N-2, 5, 8; P-4; S-1, 5.	N. S. Natarajan and M. S. R. Chari (1970a).
. . . . .	99.05 Cu, 0.85 Cr, 0.10 Si.	Chromium copper -999; annealed, k = 1.7; heat treated, k = 3.2.	. . . . .	Alloy Digest (1952-68).
. . . . .	Balance Cu, 0.4-1.0 Cr, 0.08-0.12 Ag.	Cupaloy; heat treated, k = 3.2.	. . . . .	Same as above.
. . . . .	Balance Cu, 0.4-1.2 Cr.	Mallory-3; equivalent to R.W.M.A. Group A, Class 2, and MIL-C-19311; k = 3.2.	. . . . .	Same as above.
. . . . .	Balance Cu, 0.10-0.15 Zr.	Amzirc; k = 3.4.	. . . . .	Same as above.
. . . . .	99.49 Cu, 0.50 Te, 0.01 P.	Mueller Brass Alloy 799, Tellurium Copper; equivalent to ASTM B-301-58; k = 3.7.	. . . . .	Same as above.
. . . . .	Balance Cu, 0.3 S.	Amsulf; k = 3.7.	. . . . .	Same as above.
. . . . .	99.95 Cu, 0.04 O_2.	Electrolytic Tough Pitch Copper (ETP); k = 3.90.	. . . . .	Metals Handbook (1961)
. . . . .	99.95 Cu, 0.02 P.	Deoxidized Copper, High Residual Phosphorus (DHP); k = 3.4.	. . . . .	Same as above.
. . . . .	1.0 Pb.	Free-Machining Copper (1% Pb); k = 3.9.	. . . . .	Same as above.
. . . . .	0.5 Te.	Free-Machining Copper (0.5% Te); k = 3.7.	. . . . .	Same as above.

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COPPER-NICKEL ALLOYS
(See FIGURES 43a-43c, and 43f)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
		See also the "COPPER ALLOYS" and the "COMMERCIAL COPPERS" TABLES and FIGURES.		
. . . . .	Unspecified composition.	"Neusilber"; k = 0.29 at 0°C.	. . . . .	L. Lorenz (1881b).
. . . . .	60 Cu, 40 Ni.	"Constantan"; k = 0.23 at 18°C; specific density of 8.92 at 18°C.	A-4; B-1; C-2, 3; D-1(3); E-1; F-4; G-3; S-1, 2, 3, 5.	W. Jaeger and H. Disselhorst (1900).
. . . . .	54 Cu, 46 Ni.	k = 0.21 at 18°C; specific density of 8.89.	A-1; B-1; C-2; D-1(2); F-5; G-3; S-1, 3, 5.	E. Grüneisen (1900).
L.-Ger. Silver, Plat.	#1: 62 Cu, 22 Zn, 15 Ni. #2: approx. same as #1.	#1: german silver; see COPPER ALLOYS Table and Figure. #2: "platinoid"; see COPPER ALLOYS Table and Figure.	. . . . .	C. H. Lees (1908).
. . . . .	Prepared from Kahlbaum copper and nickel. 94.6 Cu, 5.4 Ni. 89.2 Cu, 10.8 Ni. 78.6 Cu, 21.4 Ni. 58.1 Cu, 41.9 Ni.	Rolled and drawn; heated 1/2 hr. close to melting point. k = 0.87 at 0°C. k = 0.52 at 0°C. k = 0.31 at 0°C. k = 0.20 at 0°C.	A-4; B-1; C-3; D-1(2); F-4; G-3; M-2; S-1.	E. Sedström (1919).
. . . . .	60 Cu, 40 Ni.	"Eureka" or constantan; k = 0.21 at 17°C.	A-5; B-5; C-1; D-2(2); E-2; F-5; G-3.	T. Barratt and R. M. Winter (1925).
E. D.-Constantan	60 Cu, 40 Ni.	Constantan: 51 crystals/cm; also measured specimens with other crystal sizes.	A-1; B-1; D-1(2); F-4; G-3; P-1, 4; S-1, 5.	A. Eucken and K. Dittrich (1927).
. . . . .	Heddernheim; 1 Ni.	Drawn; k = 1.50 at 83 K; k = 0.62 at 21 K.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-3; L-1, 2; M-1; P-1; S-1, 5.	E. Grüneisen and E. Goens (1927).

COPPER-NICKEL ALLOYS (cont'd)

(See FIGURES 43a-43c, and 43f)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .		Values determined at 20°C. Sometimes the composition percentages add up to more than 100. The copper-nickel-magnesium alloys were deoxidized with magnesium, cold-rolled, and annealed at 800°C. The miscellaneous alloys were extensively worked, annealed, and slowly cooled (except where noted).	A-1; B-1; C-1, 2; D-1(3); F-1; G-3; M-2; S-1, 5.	C. S. Smith and E. W. Palmer (1935).
	99.73 Cu, 0.28 Ni, 0.01 Fe, 0.03 Mg.	k = 3.22.		
	99.47 Cu, 0.54 Ni, 0.02 Fe, 0.04 Mg.	k = 2.92.		
	97.94 Cu, 1.97 Ni, 0.02 Fe, 0.04 Mg.	k = 1.72.		
	94.92 Cu, 5.09 Ni, 0.01 Fe, 0.03 Mg.	k = 1.00.		
	89.90 Cu, 10.07 Ni, 0.02 Fe, 0.03 Mg, 0.02 C.	k = 0.62.		
	84.85 Cu, 15.07 Ni, 0.05 Fe, 0.01 Mg, 0.03 Mn.	k = 0.47.		
	79.68 Cu, 19.79 Ni, 0.23 Fe, 0.30 Mg.	k = 0.36.		
	69.54 Cu, 30.23 Ni, 0.05 Fe and Mg, 0.13 Mn.	k = 0.29.		
	64.14 Cu, 18.38 Ni, 17.06 Zn, 0.19 Fe, 0.3 Mn, 0.02 C.	k = 0.33.		
	63.37 Cu, 19.89 Ni, 8.22 Zn, 5.4 Pb, 3.31 Sn, 0.23 Mn, 0.14 Fe.	Sand-cast; k = 0.28.		
	96.05 Cu, 3.01 Ni, 0.88 Si, 0.004 Fe.	Quenched; k = 0.76.		
	96.05 Cu, 3.01 Ni, 0.88 Si, 0.04 Fe.	Reheated; k = 1.58.		
	96.05 Cu, 3.01 Ni, 0.88 Si, 0.04 Fe.	Furnace-cooled; k = 1.69.		
	74.07 Cu, 19.96 Ni, 5.31 Zn, 0.09 Fe.	k = 0.39.		
	64.5 Cu, 29.44 Ni, 5.69 Zn, 0.07 Fe.	k = 0.28.		

COPPER-NICKEL ALLOYS (cont'd)

(See FIGURES 43a-43c, and 43f)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Prepared from electrolytic copper and zinc, shot nickel, and cupro-manganese. #1: 62.62 Cu, 27.14 Zn, 10.05 Ni, 0.13 Mn, <0.1 C, Fe, Pb, S, Si, and Sn. #2: 63.17 Cu, 24.31 Zn, 12.33 Ni, 0.13 Mn, <0.1 C, Fe, Pb, S, Si, and Sn. #3: 62.43 Cu, 22.08 Zn, 15.35 Ni, 0.10 Mn, <0.1 C, Fe, Pb, S, Si, and Sn. #4: 62.05 Cu, 19.36 Zn, 18.40 Ni, 0.12 Mn, <0.1 C, Fe, Pb, S, Si, and Sn. #5: 62.16 Cu, 20.22 Ni, 17.44 Zn, 0.13 Mn, <0.1 C, Fe, Pb, S, Si, and Sn. #6: 61.96 Cu, 25.56 Ni, 12.31 Zn, 0.10 Mn, <0.1 C, Fe, Pb, S, Si, and Sn. #7: 62.02 Cu, 29.77 Ni, 7.93 Zn, 0.14 Mn, <0.1 C, Fe, Pb, S, Si, and Sn.	Melted in plumbago crucibles; cast in iron mold; annealed at 800°C. #1: k = 0.37 at 20°C. #2: k = 0.30 at 20°C. #3: k = 0.27 at 20°C. #4: k = 0.23 at 20°C. #5: k = 0.22 at 20°C. #6: k = 0.21 at 20°C. #7: k = 0.19 at 20°C.	A-1; B-1; C-1,2; D-1(3); F-1; G-3.	M. Cook (1936).
. . . . .	Balance Cu, Ni, 0.0042 Fe, 0.0014 Pb, trace of Sn and Zn. #1: 0.022 O_2. #2: 0.079 O_2. #1(a): 0.106 Ni. #1(b): 0.303 Ni. #1(c): 0.508 Ni. #2(a): 0.106 Ni. #2(b): 0.204 Ni. #2(c): 0.303 Ni. #2(d): 0.777 Ni.	At 0°C: #1(a), k = 3.8; #1(b), k = 3.5; #1(c), k = 3.3; #2(a), k = 3.8; #2(b), k = 3.6; #2(c), k = 3.5; #2(d), k = 3.3.	A-1; B-1; C-1,2; D-1(6); F-4; G-3; M-2.	W. F. Chubb (1938).

COPPER-NICKEL ALLOYS (cont'd)

(See FIGURES 43a-43c, and 43f)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
K.S.-Ger. silver	64 Cu, 20 Zn, 16 Ni.	"Neusilber"; see COPPER ALLOYS Table and Figure.	. . . . .	J. Karweil and K. Schäfer (1939).
K.S.-Bronze	46 Cu, 41 Zn, 13 Ni.	"Silberbronze"; see COPPER ALLOYS Table and Figure.	. . . . .	Same as above.
. . . . .	#1: balance Cu, 49.75 Ni, 0.05 Mn, 0.03 Fe.	#1: k = 0.161 at 78 K.	A-1; B-1; C-1; D-1(2); E-2; F-4; G-3; M-2; S-1, 5.	S. Aoyama and T. Ito (1940).
	#2: balance Cu, 39.84 Ni, 0.04 Fe, 0.02 Mn.	#2: k = 0.178 at 78 K.		
	#3: balance Cu, 29.89 Ni, 0.03 Fe and Mn.	#3: k = 0.202 at 78 K.		
	#4: balance Cu, 19.83 Ni, 0.04 Mn, 0.02 Fe.	#4: k = 0.234 at 78 K.		
	#5: balance Cu, 13.84 Ni, 0.11 Fe, trace Mn.	#5: k = 0.280 at 78 K.		
	#6: balance Cu, 9.47 Ni, 0.14 Fe, trace Mn.	#6: k = 0.350 at 78 K.		
	#7: balance Cu, 3.67 Ni, 0.09 Fe, trace Mn.	#7: k = 0.70 at 78 K.		
	#8: balance Cu, 1.03 Ni, 0.03 Fe, trace Mn.	#8: k = 1.76 at 78 K.		
A.M.-Ger. silver	45.9 Cu, 42.1 Zn, 9.8 Ni, 2.0 Pb, 0.15 Fe, 0.05 Mn.	"German silver"; see COPPER ALLOYS Table and Figure.	. . . . .	J.F. Allen and E. Mendoza (1947).
. . . . .	#1: Henry Righton; 63 Cu, 20 Ni, 17 Zn. #2: Yorkshire Copper Works; 70 Cu, 30 Ni.	#1: "nickel-silver; k = 0.0255 at 10 K; k = 0.0485 at 15 K; k = 0.0711 at 20 K. #2: "cupro-nickel"; k = 0.0209 at 10 K; k = 0.0356 at 15 K; k = 0.0502 at 20 K.	A-1; B-5; C-2; D-5(1); E-5; F-4; G-3; M-1.	K.R. Wilkinson and J. Wilks (1949).
P.Z.J.-constantan	Driver-Harris; 55 Cu, 45 Ni.	Constantan (advance).	A-1; B-1; C-1; D-1(2); E-1; F-2; G-2; L-1, 2; M-1.	R.W. Powers, J.B. Ziegler, and H.L. Johnston (1951c).

COPPER-NICKEL ALLOYS (cont'd)

(See FIGURES 43a-43c, and 43f)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
H. -Cu+20 Ni	Johnson, Matthey; 80 Cu, 20 Ni.	Average radial and axial grain size of 0.011 mm. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-4(2); E-5; F-4; G-2; L-1, 2; M-1; O-3; P-1, 4; Q-1; S-1.	J. K. Hulm (1951).
B. -constantan	60 Cu, 40 Ni.	317 enamelled wires of 36-gauge in parallel.	A-1; B-1; C-1; D-3, 4(2); E-4; F-4; G-2; L-1; M-1; O-1; P-2; Q-1; S-1.	R. Berman (1951b).
B. -Ger. silver	47 Cu, 41 Zn, 9 Ni, 2 Pb.	See COPPER ALLOYS Table and Figure.	. . . . .	Same as above.
E. Z. -Cu + 10 Ni, Cu+10 Ni(ann)	Westinghouse Electric; 90 Cu, 10 Ni.	Cu + 10 Ni(ann): two specimens, one machined to size and annealed, the other was a single crystal. Cu + 10 Ni: two specimens, one cold-worked and machined, the other severely cold-worked and machined. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-4(2); E-5; F-4; G-2; N-5; P-3, 4; S-1, 5.	I. Estermann and J. E. Zimmerman (1952).
Z. Z. -German silver, German silver(ann.)	German silver: 81 Cu, 19 Ni.	Not tempered. German silver(ann): same specimen, tempered up to 800°C.	A-1; B-1; C-1; D-3(2); E-3, 5; G-3; L-1; M-1.	N. V. Zavaritskii and A. C. Zeldovich (1956).
. . . . .	. . . . .	Graph of effect of plastic strain on the lattice thermal conductivity of Cu-Ni alloys at 4.2 K.	. . . . .	J. C. Erdmann and J. A. Jahoda (1964).
		All values below are at room temperature.		
. . . . .	>99.5 Cu, 19.0-23.0 Ni, 1.0 Fe, Mn, and Zn, 0.05 Pb.	Copper Alloy No. 710; k = 0.35.	. . . . .	Alloy Digest (1952-68).
. . . . .	Balance Cu, 1.40-1.50 Ni, 0.20-0.35 Be.	Conduloy; k = 0.83.	. . . . .	Same as above.
. . . . .	Balance Cu, 1.5-2.0 Ni, 0.35-0.50 Be.	Mallory 53B; k = 1.8.	. . . . .	Same as above.
. . . . .	97.5 Cu, 1.9 Ni, 0.6 Si.	Nironze 635; k = 1.04.	. . . . .	Same as above.
. . . . .	97.50 Cu, 1.9 Ni, 0.6 Si.	Cunisil-837; k = 1.6.	. . . . .	Same as above.

COPPER-NICKEL ALLOYS (cont'd)

(See FIGURES 43a-43c, and 43f)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Balance Cu, 1.6-2.2 Ni, 0.50 Zn, 0.4-0.8 Si, 0.10 Pb.	Cunisil-647; equivalent to ASTM 411; k = 1.6.	. . . . .	Alloy Digest (1952-68).
. . . . .	Balance Cu, 10.0 Ni, 1.5 Fe.	Revere No. 508; k = 0.47.	. . . . .	Same as above.
. . . . .	> 86.5 Cu, 9.0-11.0 Ni, 1.0 Mn and Zn, 0.5-2.0 Fe, and 0.05 Pb.	Cupro Nickel, 10%-755; equivalent to ASTM B111 and B171; k = 0.45.	. . . . .	Same as above.
. . . . .	Balance Cu, 9.0 Sn, 3.50-4.50 Ni, 2.0 Zn.	Nicuite; k = 0.52.	. . . . .	Same as above.
. . . . .	78.0-85.0 Cu, 9.0-11.0 Al, 4.5-5.5 Ni, 2.0-4.0 Fe, 1.5 Mn, 0.25 Si, 0.20 Sn.	Ambraloy 917; k = 0.38.	. . . . .	Same as above.
. . . . .	78.00-82.00 Cu, 9.70-10.90 Al, 4.50-5.50 Ni, 2.00-3.50 Fe, 1.50 Mn.	Tuf Stuf 224 K; equivalent to AMS 4640, ASTM B150 alloy 2, ASTM B124 alloy 11 b, SAE 701 c; k = 0.38.	. . . . .	Same as above.
. . . . .	Balance Cu, 19.0-23.0 Ni, 1.0 Fe, Mn, and Zn, 0.05 Pb.	Bridgeport Alloy No. 520; equivalent to ASTM B111 and B122; k = 0.35.	. . . . .	Same as above.
. . . . .	78.0-82.0 Cu, 9.0-11.0 Al, 3.0-6.0 Fe and Ni, 1.0-2.0 Mn.	Nialite; equivalent to ASTM 148 alloy 9D; k = 0.66.	. . . . .	Same as above.
. . . . .	Balance Cu, 22.75-23.00 Ni.	Midohm; k = 0.34.	. . . . .	Same as above.
. . . . .	> 78.0 Cu, 8.5-10.5 Al, 4.5-6.0 Ni, 2.5-5.5 Fe, 0.5-3.5 Mn.	Ni-Bral; equivalent to ASTM B124 and B148, and SAE 68A; k = 0.38.	. . . . .	Same as above.
. . . . .	Balance Cu, 11.0-14.0 Mn, 7.5-8.5 Al, 2.0-4.0 Fe, 1.5-4.5 Ni, 1.0 Sn, 0.15 Si, 0.05 P and Pb, 0.30 total impurities.	Superston 40; equivalent to MIL-B-21230A; k = 0.12.	. . . . .	Same as above.

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COPPER-NICKEL ALLOYS (cont'd)

(See FIGURES 43a-43c, and 43f)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Balance Cu, 29.0-33.0 Ni, 1.0 Mn, 0.4-0.7 Fe.	Cufenloy-30; k = 0.29.	. . . . .	Alloy Digest (1952-68).
. . . . .	64.0-66.5 Cu, 17.0-19.0 Ni, 0.50 Mn, 0.10 Fe and Pb, balance Zn.	Revere No. 533; equivalent to ASTM B112 alloy 2, B122 alloy 2, B151 alloy A, and B 206 alloy A; k = 0.33.	. . . . .	Same as above.
. . . . .	64.0-66.0 Cu, 11.0-13.0 Ni, 1.75-2.25 Pb, 0.05-0.50 Mn, balance Ni.	Revere No. 575; k = 0.40.	. . . . .	Same as above.
. . . . .	63.5-66.5 Cu, 11.0-13.0 Ni, 0.50 Mn, 0.25 Fe, 0.10 Pb, 0.30 total other impurities, balance Zn.	Nickel Silver 65-12; equivalent to Seymour 12A1; k = 0.40.	. . . . .	Same as above.
. . . . .	63.0-66.5 Cu, 17.0 Zn, 16.5-19.5 Ni, 0.50 Mn, 0.25 Fe, 0.10 Pb.	Nickel Silver 65-18; equivalent to ASTM 122 alloy 2, B151 alloy A, and B206 alloy A; k = 0.33.	. . . . .	Same as above.
. . . . .	64.15 Cu, 30.00 Ni, 5.25 Fe, 0.60 Mn.	Cupro Nickel, 30%-707; k = 0.29.	. . . . .	Same as above.
. . . . .	60.0 Cu, 18.0 Ni, 0.50 Mn, 0.25 Fe, 0.10 Pb, balance Zn.	Riverside No. 4; equivalent to ASTM B151-B and B206-B; k = 0.29.	. . . . .	Same as above.
. . . . .	Balance Cu, 20 Ni, 20 Mn.	Conflex 720 Alloy; k = 0.20.	. . . . .	Same as above.
. . . . .	60 Cu, 20 Ni, 20 Mn.	C.D.C. Manganese Alloy No. 720; soft, k = 0.20; hard, k = 0.32.	. . . . .	Same as above.
. . . . .	54.0-55.0 Cu, 3.0 Mn, 0.1 C, balance Ni.	Advance; equivalent to constantan, Ideal, and Ferry; k = 0.194.	. . . . .	Same as above.

COPPER-NICKEL ALLOYS (cont'd)

(See FIGURES 43a-43c, and 43f)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	53.5-56.5 Cu, 16.5-19.5 Ni, 0.50 Mn, 0.25 Fe, 0.10 Pb, balance Zn.	Nickel Silver 55-18; equivalent to ASTM B122 alloy 4, B151-B, B206-B, and Revere No. 255; k = 0.29.	. . . . .	Alloy Digest (1952-68).
. . . . .	53.5-56.5 Cu, 16.5-19.5 Ni, 0.50 Mn, 0.25 Fe, 0.10 Pb, balance Zn.	Revere No. 770; equivalent to ASTM B122 alloy 4 B151-B, and B206-B; k = 0.29.	. . . . .	Same as above.
. . . . .	46.0-49.0 Cu, 8.15-10.15 Ni, 1.75-2.75 Pb, 0.25 Mn, 0.75 other metals, balance Zn.	Mueller 515; k = 0.47.	. . . . .	Same as above.

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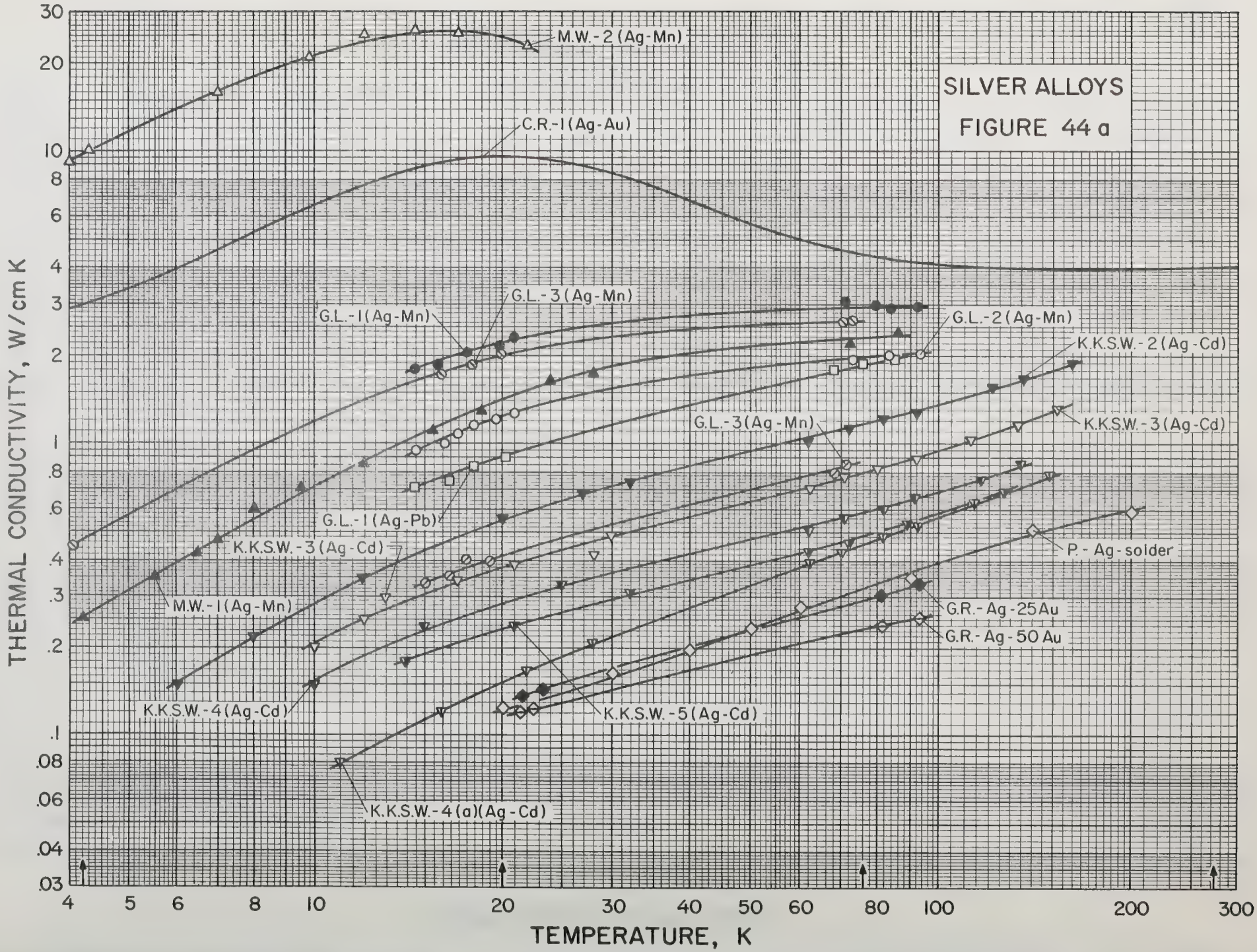
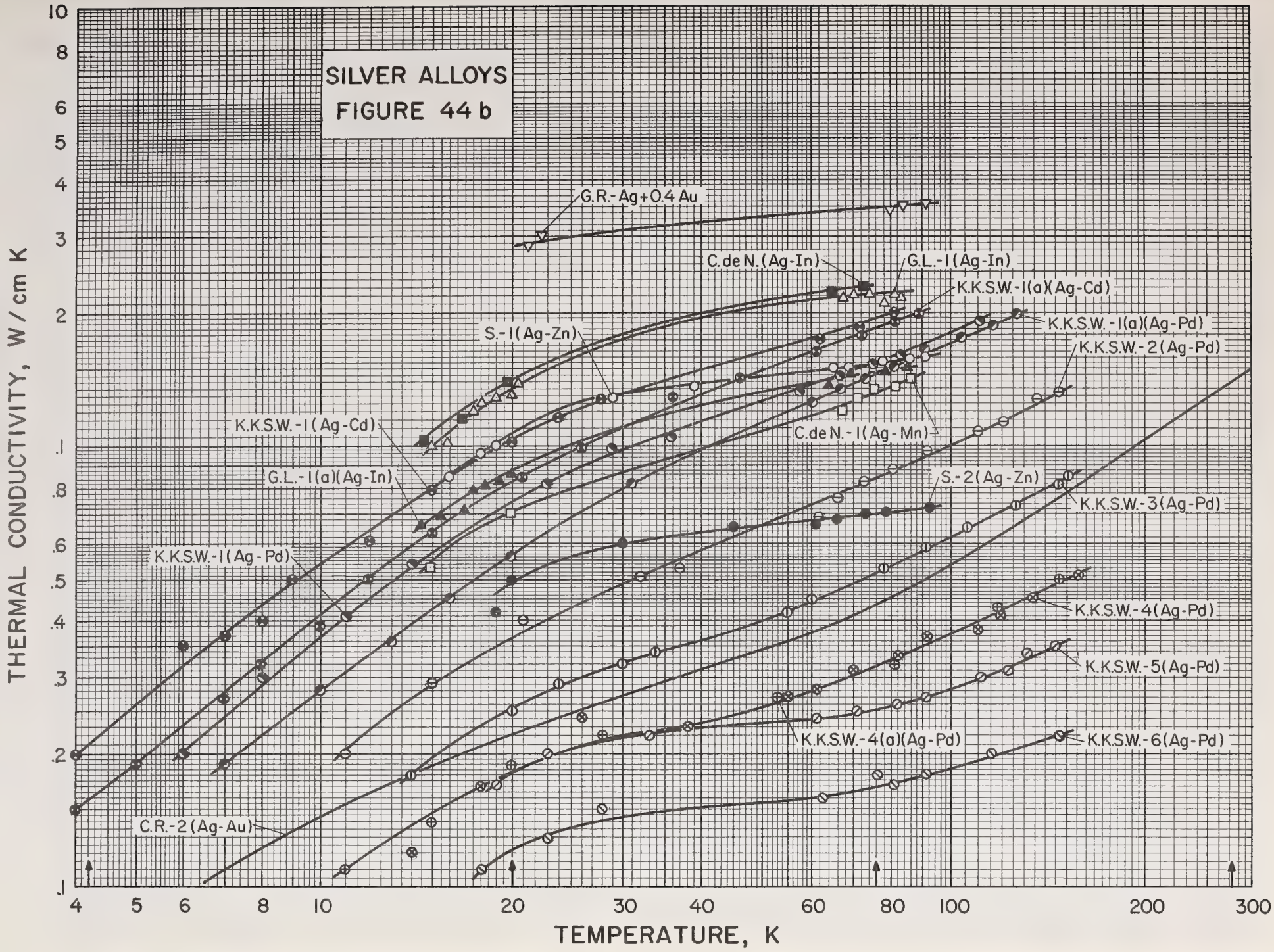
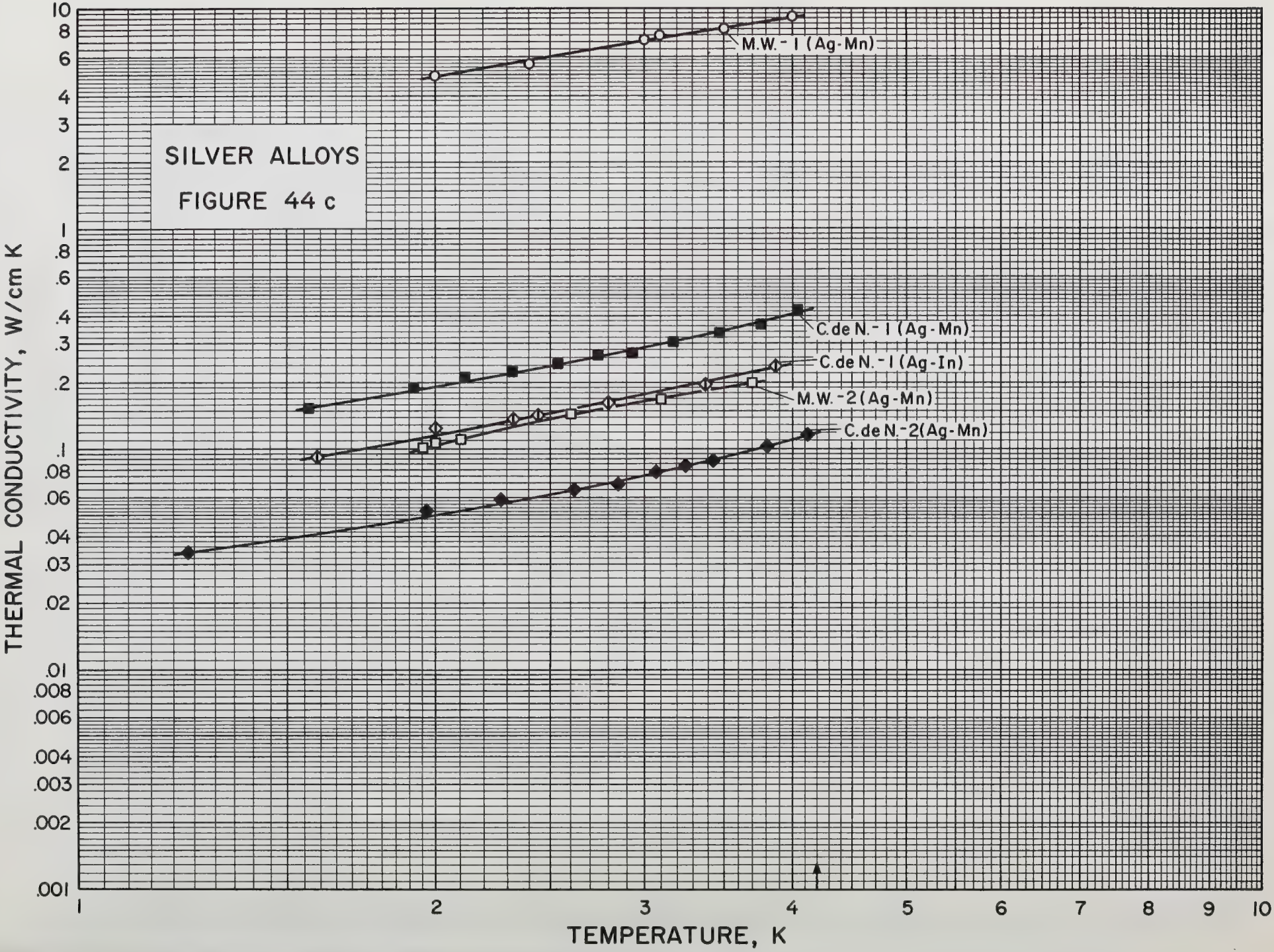

SILVER ALLOYS
FIGURE 44 a
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
M.W.-2 (Ag-Mn)
C.R.-1 (Ag-Au)
G.L.-3 (Ag-Mn)
G.L.-1 (Ag-Mn)
G.L.-2 (Ag-Mn)
K.K.S.W.-2 (Ag-Cd)
G.L.-3 (Ag-Mn)
K.K.S.W.-3 (Ag-Cd)
G.L.-1 (Ag-Pb)
K.K.S.W.-3 (Ag-Cd)
P.-Ag-solder
M.W.-1 (Ag-Mn)
G.R.-Ag-25Au
G.R.-Ag-50Au
K.K.S.W.-4 (Ag-Cd)
K.K.S.W.-5 (Ag-Cd)
K.K.S.W.-4 (a) (Ag-Cd)


SILVER ALLOYS
FIGURE 44 b
THERMAL CONDUCTIVITY, W / cm K
TEMPERATURE, K
G.R.-Ag+0.4 Au
C.de N.(Ag-In)
G.L.-1(Ag-In)
K.K.S.W.-1(a)(Ag-Cd)
K.K.S.W.-1(a)(Ag-Pd)
K.K.S.W.-2(Ag-Pd)
S.-1(Ag-Zn)
K.K.S.W.-1(Ag-Cd)
C.de N.-1(Ag-Mn)
G.L.-1(a)(Ag-In)
S.-2(Ag-Zn)
K.K.S.W.-3(Ag-Pd)
K.K.S.W.-1(Ag-Pd)
K.K.S.W.-4(Ag-Pd)
K.K.S.W.-5(Ag-Pd)
K.K.S.W.-4(a)(Ag-Pd)
K.K.S.W.-6(Ag-Pd)
C.R.-2(Ag-Au)


SILVER ALLOYS
FIGURE 44 c
M.W. - 1 (Ag-Mn)
C.de N. - 1 (Ag-Mn)
C.de N. - 1 (Ag-In)
M.W. - 2 (Ag-Mn)
C.de N. - 2 (Ag-Mn)
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
.01
.008
.006
.004
.003
.002
.001
1
2
3
4
5
6
7
8
9
10

SILVER ALLOYS
(See FIGURES 44a–44c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Heraeus. 90(weight) Ag, 10 Pd. 80 Ag, 20 Pd. 70 Ag, 30 Pd. 60 Ag, 40 Pd. 50 Ag, 50 Pd. 90 Ag, 10 Pt. 75 Ag, 25 Pt. 70 Ag, 30 Pt. 67 Ag, 33 Pt.	. . . . . . k = 1.41 at 25°C. k = 0.84 at 25°C. k = 0.57 at 25°C. k = 0.45 at 25°C. k = 0.32 at 25°C. k = 0.98 at 25°C. k = 0.38 at 25°C. k = 0.31 at 25°C. k = 0.30 at 25°C.	A-4; B-1; C-3; G-2; M-2; S-1, 5.	F.A. Schulze (1911)
. . . . .	Prepared from Nordiska Ag, and Merck Cd, Au, and Zn. 95.0(atomic) Ag, 5.0 Au. 90.3 Ag, 9.7 Au. 80.0 Ag, 20.0 Au. 69.8 Ag, 30.2 Au. 60.3 Ag, 39.7 Au. 54.6 Ag, 45.4 Au. 96.0 Ag, 4.0 Cd. 91.2 Ag, 8.8 Cd. 88.1 Ag, 11.9 Cd. 83.2 Ag, 16.8 Cd. 94.3 Ag, 5.7 Zn. 88.4 Ag, 11.6 Zn. 80.1 Ag, 19.9 Zn. 72.3 Ag, 27.7 Zn.	Rolled and drawn; heated $\frac{1}{2}$ hr near melting point. k = 2.08 at 273K. k = 1.42 at 273K. k = 0.91 at 273K. k = 0.81 at 273K. k = 0.73 at 273K. k = 0.72 at 273K. k = 2.03 at 273K. k = 1.52 at 273K. k = 1.41 at 273K. k = 1.36 at 273K. k = 1.56 at 273K. k = 1.00 at 273K. k = 0.76 at 273K. k = 0.70 at 273K.	A-4; B-1; C-3; D-1(2); F-4; G-3; M-2; S-1.	E. Sedström (1919).
G.R.-Ag + 0.4 Au, Ag + 25 Au, Ag + 50 Au	Ag + 0.4 Au: 99.63 Ag, 0.37 Au. Ag + 25 Au: 75 Ag, 25 Au. Ag + 50 Au: 50 Ag + 50 Au.	Specimens Ag + 25 Au and Ag + 50 Au were single crystals.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-3; L-1; M-2; P-1, 2; S-1, 5.	E. Grüneisen and H. Reddemann (1934).
P.-Ag-solder	50 Ag, 18 Cd, 16.5 Zn, 15.5 Cu.	"Easy-Flo"; melted into carbon block, drawn, annealed.	A-1; B-1; C-1; D-1(8); E-2, 5; F-2; G-2.	R.L. Powell (1953).

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SILVER ALLOYS (cont'd)

(See FIGURES 44a–44c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
K.K.S.W.-1 (Ag-Pd), 1(a) (Ag-Pd), 2 (Ag-Pd), 3 (Ag-Pd), 4 (Ag-Pd), 5 (Ag-Pd), 6 (Ag-Pd).	Johnson, Matthey. #1: 97.92 (weight) Ag, 2.08 Pd; RRR (20) = 2.8. #1(a): same as #1; RRR(20) = 2.7. #2: 94.94 Ag, 5.06 Pd; RRR(20) = 1.77. #3: 90.1 Ag, 9.9 Pd; RRR (20) = 1.44. #4: 79.92 Ag, 20.08 Pd. #4(a): same as #4; RRR(20) = 1.22. #5: 70.38 Ag, 29.62 Pd; RRR (20) = 1.15. #6: 50 Ag, 50 Pd; RRR(20) = 1.10.	#1: annealed at 610°C. #1(a): strained. #2: annealed at 610°C. #3: annealed at 650°C. #4: annealed at 650°C. #4(a): annealed at 800°C. #5: annealed at 800°C. #6: annealed at 880°C. Specimen of 60 Ag + 40 Pd concentration also measured with results between #5 and #6. Specimens of 70 Pd + 30 Ag and 95 Pd + 5 Ag also measured; see Palladium Alloys Table and Figure. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-4(2); E-1, 5; F-4; G-1; L-1, 2, 9; M-2; N-5; P-2, 3; Q-1, 2; S-1, 5.	W.R.G. Kemp, P. G. Klemens, A.K. Sreedhar, and G. K. White (1956); see also Kemp, Klemens, Sreedhar, and White (1954).
K.K.S.W.-1 (Ag-Cd), 1(a) (Ag-Cd), 2 (Ag-Cd), 3 (Ag-Cd), 4 (Ag-Cd), 4(a) (Ag-Cd), 5 (Ag-Cd)	Johnson, Matthey. #1: 98.04 Ag, 1.96 Cd; RRR(20) = 3.6. #1(a): same as #1; RRR(20) = 3.6. #2: 95.09 Ag, 4.91 Cd; RRR(20) = 2.27. #3: 90.49 Ag, 9.51 Cd. #4: 80.79 Ag, 19.21 Cd. #4(a): same as #4. #5: 70.03 Ag, 29.97 Cd; RRR(20) = 1.69.	#1: annealed at 530°C. #1(a): strained. #2: annealed at 530°C. #3: annealed at 500°C. #4: annealed at 500°C. #4(a): specimen #4 strained. #5: annealed at 500°C. Specimen #3 measured after anneal at 610°C: results between 70 and 100 K same as #3. Specimen #4 recast: results same as #4 between 10 and 90 K. Graph of lattice thermal conductivity.	Same as above.	W.R.G. Kemp, P. G. Klemens, A.K. Sreedhar, and G. K. White (1956); see also W.R.G. Kemp and P.G. Klemens (1960).
G.L.-1(Ag-Mn), 2(Ag-Mn), 3 (Ag-Mn), 1 (Ag-In), 1 (Ag-Pb)	Prepared from Nordiska Affiveriet pure silver and high purity In, Mn, and Pb. #1(Ag-Mn): 0.14(atomic) Mn; RRR = 7.25. #2(Ag-Mn): 0.32 Mn; RRR = 3.77. #3 (Ag-Mn): 22.2 Mn; RRR = 1.21. #1(Ag-In): 0.24 In; RRR = 4.48. #1(Ag-Pb): 0.13 Pb; RRR = 3.26.	Alloys melted in evacuated, sealed silica tubes in high frequency furnace, rolled, cut. All specimens annealed in vacuum at 720 K. Specimen of Ag + 0.55 Mn also measured with results 50% lower than G.L.-2(Ag-Mn) at low temperatures and 15% lower at high temperatures. Specimens of Ag + 0.52 In and Ag + 0.2 Pb also measured; results were 50% lower than G.L.-1(Ag-In) at low temperatures and 15% lower than G.L.-1(Ag-Pb) at high temperatures.	A-1; B-1; C-1; D-2; E-8; G-2; L-1, 2; M-1; N-1; P-1.	A.N. Gerritsen and J.O. Linde (1956).
. . . . .	. . . . .	Graph of lattice thermal conductivity of Ag + 0.3 Sn alloy.	. . . . .	G.K. White, S.B. Woods, and M.T. Elford (1959).

SILVER ALLOYS (cont'd)
(See FIGURES 44a–44c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
C.de N.-1(Ag-Mn), 2(Ag-Mn), 1(Ag-In)	Prepared from pure silver and high manganese and indium, $< 5 \times 10^{5}$ parts of impurity. #1 (Ag-Mn): 0.14(atomic) Mn. #2(Ag-Mn): 0.55 Mn. #1(Ag-In): 0.24 In.	Specimens prepared by melting in evacuated silica tubes in high frequency furnace, rolled, and cut. Specimen of Ag + 0.32 Mn composition measured also, with results between #1 and #2(Ag-Mn). Also measured in magnetic fields of 1.2, 1.9, and 2.5 T between 1 and 4K, increasing the thermal conductivity up to 26% in highest field. Graph of intrinsic electronic and lattice thermal conductivity.	A-1; B-1; C-1; D-2, 3(2); E-5; F-4; G-2; L-1; M-2; N-2; P-3, 10; Q-1, 5; R-2; S-1.	M.S.R. Chari and J.de Nobel (1959a) and (1959c); see also M.S.R. Chari (1962).
. . . . .	Ag Sb and Ag Sn.	Extensive study of lattice thermal conductivity as a function of alloy, dislocations, boundaries, electrons, and scattering mechanisms.	. . . . .	M.H. Jericho (1965).
M.W.-1(Ag-Mn), 2(Ag-Mn)	#1(Ag-Mn): prepared from Cominco 99.9999 Ag and Johnson, Matthey and Mallory 99.95 pure electrolytic Mn; 99.995(atomic) Ag, 0.005 Mn. #2(Ag-Mn): prepared from Cominco 99.999 Ag and same Mn as #1: 99.69 Ag, 0.31 Mn.	Prepared by melting in alumina crucibles in an induction furnace, chill cast, rolled, drawn, etched, annealed for 4 hrs. at 2×10^{-4} Torr at 750°C. Two other specimens with 0.067 and 0.11% Mn also measured, with intermediate results between #1 and #2.	A-1; B-1; C-1; D-4(2); E-1, 5; F-4; G-2; L-1, 2; M-2, 6; N-8; S-1, 2, 5.	H.L. Malm and S. B. Woods (1966).
C.R.-1(Ag-Au), 2(Ag-Au)	Cambridge Metals Research; prepared from 6N Au and Ag. #1: 0.09(atomic) Au; RRR = 46.5. #2: 27.0 Au; RRR = 1.25.	Drawn, etched, washed in distilled water and alcohol, dried, sealed in quartz capsules with 1/3 atmosphere of oxygen, annealed 72 hrs. at 900°C. Other specimens with 0.69(atomic)%, 0.79, 1.37, 1.65, 2.2, 5.3, 5.7, and 10.0 also measured, with intermediate results. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-2, 3; F-4; G-2; L-1; M-2; N-1; O-3; P-1; Q-1; S-2.	R.S. Crisp and J. Rungis (1970).
S. 1, 2(Ag-Zn)	Johnson, Matthey; prepared from spectrographically pure rods of silver and zinc. #1: Ag + 2 Zn. #2: Ag + 4.46 Zn.	Melted in vacuum in quartz tube at 1000°C, shaken in molten condition; reduced to 850-900°C, annealed for 11 days, rolled and reannealed at 500°C for several hours.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-3; L-1; M-1; O-2, 3, 9; Q-1; S-1.	B. N. Srivastava, S. Chatterjee, S. K. Sen, and D. K. Chakraborty (1970).

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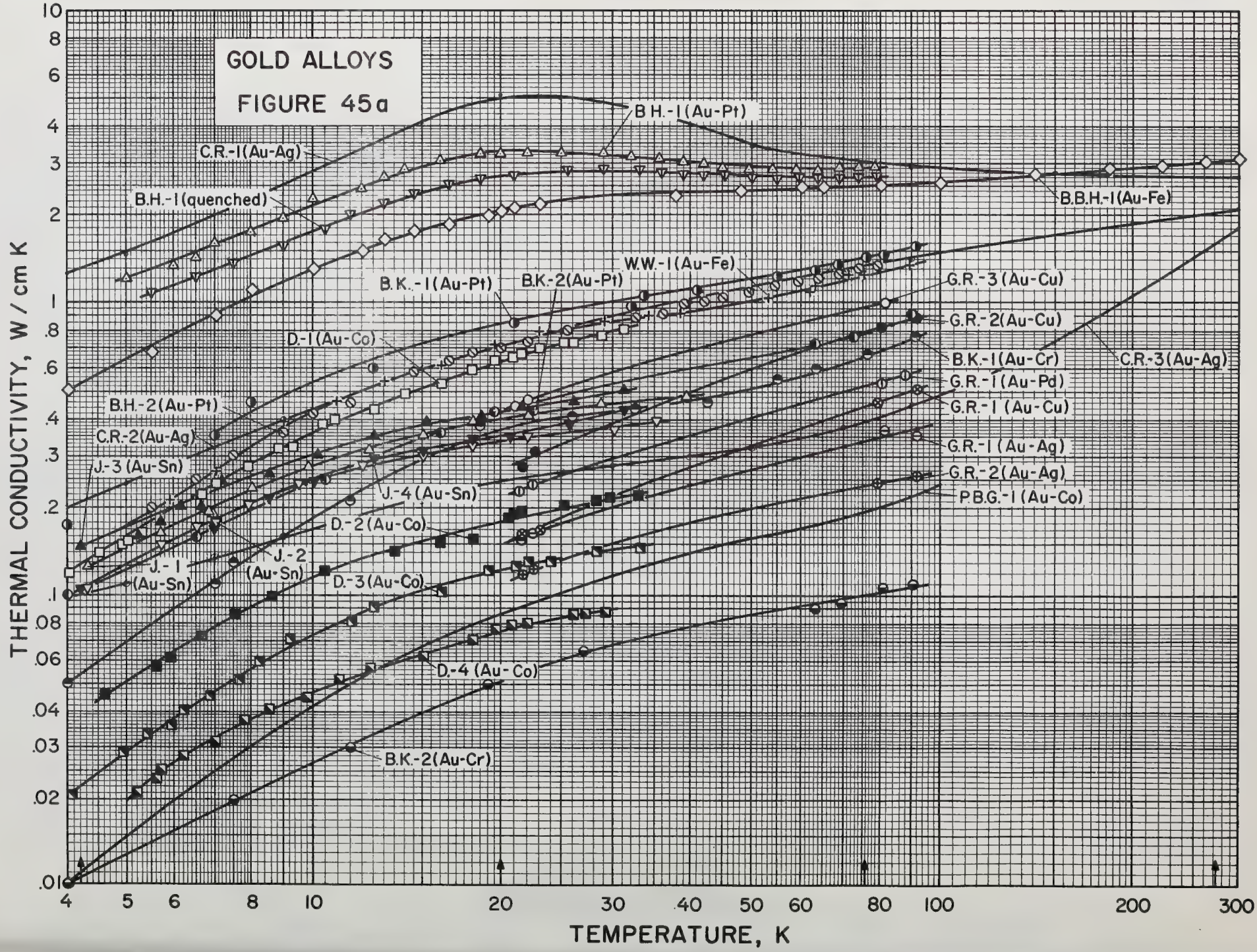
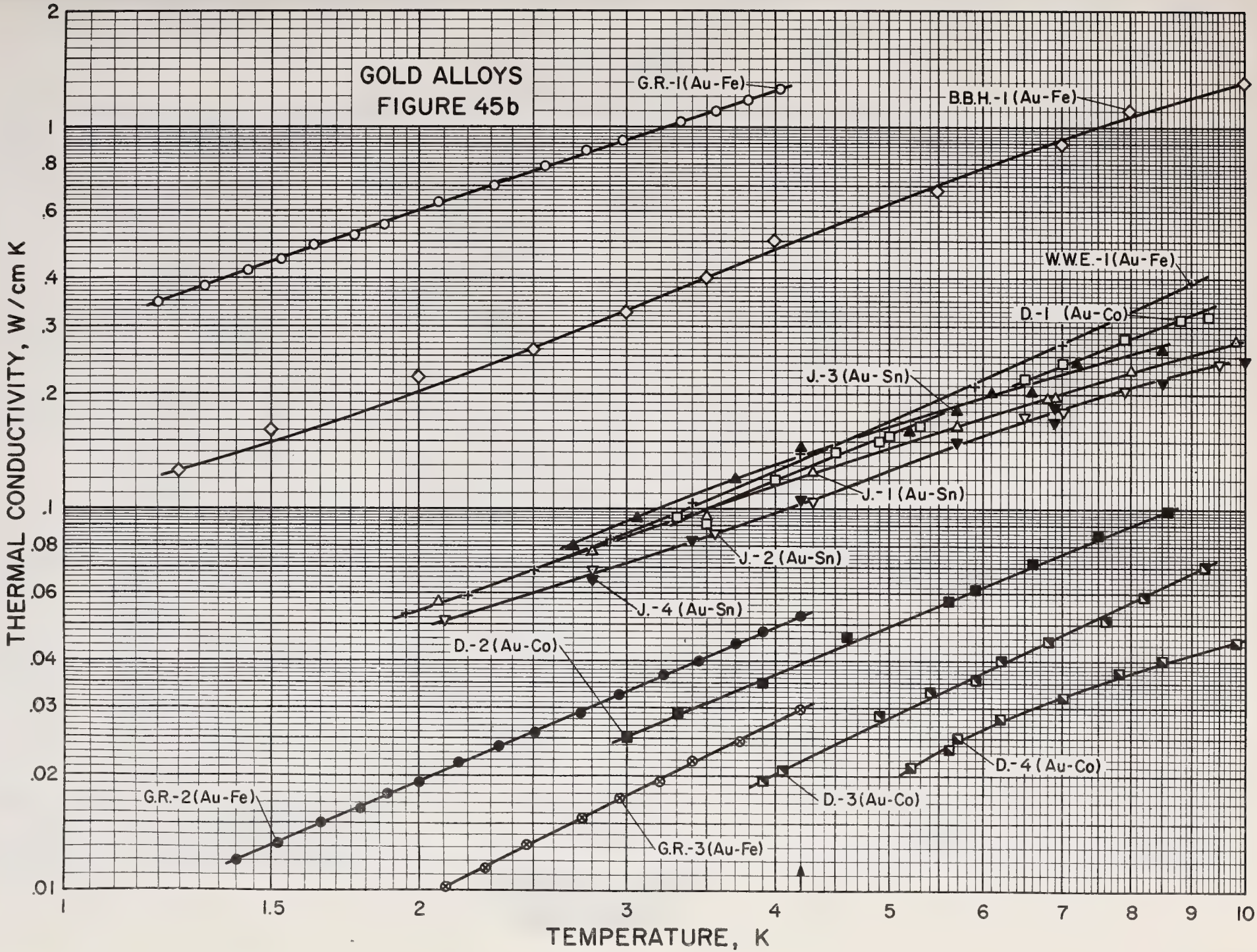

GOLD ALLOYS
FIGURE 45a
THERMAL CONDUCTIVITY, W / cm K
TEMPERATURE, K
B H.-1 (Au-Pt)
C.R.-1 (Au-Ag)
B.H.-1 (quenched)
B.B.H.-1 (Au-Fe)
W.W.-1 (Au-Fe)
B.K.-1 (Au-Pt)
B.K.-2 (Au-Pt)
G.R.-3 (Au-Cu)
G.R.-2 (Au-Cu)
D.-1 (Au-Co)
B.K.-1 (Au-Cr)
C.R.-3 (Au-Ag)
G.R.-1 (Au-Pd)
B.H.-2 (Au-Pt)
G.R.-1 (Au-Cu)
C.R.-2 (Au-Ag)
G.R.-1 (Au-Ag)
J.-3 (Au-Sn)
G.R.-2 (Au-Ag)
J.-4 (Au-Sn)
P.B.G.-1 (Au-Co)
D.-2 (Au-Co)
J.-2 (Au-Sn)
J.-1 (Au-Sn)
D.-3 (Au-Co)
D.-4 (Au-Co)
B.K.-2 (Au-Cr)


GOLD ALLOYS
FIGURE 45b
G.R.-1(Au-Fe)
B.B.H.-1 (Au-Fe)
W.W.E.-1(Au-Fe)
D.-1 (Au-Co)
J.-3 (Au-Sn)
J.-1 (Au-Sn)
J.-2 (Au-Sn)
J.-4 (Au-Sn)
D.-2(Au-Co)
D.-4 (Au-Co)
D.-3(Au-Co)
G.R.-2(Au-Fe)
G.R.-3(Au-Fe)
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
2
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
.01
1
1.5
2
3
4
5
6
7
8
9
10

GOLD ALLOYS
(See FIGURES 45a and 45b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Heraeus.	. . . . .	A-4; B-1; C-3; G-2; M-2; S-1, 5.	F. A. Schulze (1911).
	90 (weight) Au, 10 Pd	k = 0.98 at 25°C.		
	80 Au, 20 Pd.	k = 0.59 at 25°C.		
	70 Au, 30 Pd.	k = 0.44 at 25°C.		
	60 Au, 40 Pd.	k = 0.40 at 25°C.		
	50 Au, 50 Pd.	k = 0.36 at 25°C.		
	90 Au, 10 Pt.	k = 0.76 at 25°C.		
	80 Au, 20 Pt.	k = 0.41 at 25°C.		
	70 Au, 30 Pt.	k = 0.30 at 25°C.		
	60 Au, 40 Pt.	k = 0.26 at 25°C.		
. . . . .	Prepared from Nordiska Au, Cd, and Zn, Merck Ag, and Kahlbaum Cu.	Specimens rolled and drawn; heated $\frac{1}{2}$ hr. near melting point.	A-4; B-1; C-3; D-1(2); F-4; G-3; M-2; S-1.	E. Sedström (1919) and (1924).
	55.1 (atomic) Au, 44.9 Ag.	k = 0.73 at 273 K.		
	59.9 Au, 40.1 Ag.	k = 0.68 at 273 K.		
	70.3 Au, 29.7 Ag.	k = 0.78 at 273 K.		
	81.3 Au, 18.7 Ag.	k = 0.96 at 273 K.		
	89.3 Au, 10.7 Ag.	k = 1.36 at 273 K.		
	95.1 Au, 4.9 Ag.	k = 1.84 at 273 K.		
	90.5 Au, 9.5 Cu.	k = 1.09 at 273 K.		
	80.0 Au, 20.0 Cu.	k = 0.67 at 273 K.		
	69.8 Au, 30.2 Cu.	k = 0.56 at 273 K.		
	94.6 Au, 5.4 Cd.	k = 1.23 at 273 K.		
	91.3 Au, 8.7 Cd.	k = 0.95 at 273 K.		
	82.2 Au, 17.2 Cd.	k = 0.72 at 273 K.		
	95.1 Au, 4.9 Zn.	k = 1.17 at 273 K.		
	89.9 Au, 10.1 Zn.	k = 0.67 at 273 K.		
	53.5 Au, 46.5 Cu.	k = 0.92 at 273 K.		
	53.7 Au, 46.3 Cu.	k = 0.85 at 273 K.		
	54.7 Au, 45.3 Cu.	k = 0.72 at 273 K.		
	59.6 Au, 40.4 Cu.	k = 0.51 at 273 K.		
	60.2 Au, 39.8 Cu.	k = 0.83 at 273 K.		
	69.2 Au, 30.8 Cu.	k = 0.50 at 273 K.		
	83.8 Au, 16.2 Cu.	k = 0.73 at 273 K.		

GOLD ALLOYS (cont'd)

(See FIGURES 45a and 45b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Heraeus. 92 (atomic) Au, 8 Pt. 82 Au, 16 Pt. 68 Au, 32 Pt. 55 Au, 45 Pt.	Annealed at 800°C; single phase. k = 0.80 at 18°C. k = 0.48 at 18°C. k = 0.23 at 18°C. k = 0.21 at 18°C.	A-4; B-1; C-3; D-1(2); F-4; G-3; L-2; S-1, 2, 4.	C.H. Johansson and J.O. Linde (1930).
G.R.-1(Au-Ag), 2(Au-Ag)	#1 (Au-Ag): 75 Au, 25 Ag. #2 (Au-Ag): 50 Au, 50 Ag.	Single crystals.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-3; L-1; M-2; P-1; S-1, 5.	E. Grüneisen and H. Reddemann (1934).
G.R.-1(Au-Cu), 2(Au-Cu), 3(Au-Cu)	Degussa; #1(Au-Cu): 91 Au, #2(Au-Cu): 73.7 Au, 26.4 Cu. #3(Au-Cu): 50.1 Au, 44.9 Cu.	#1 and #2: polycrystals. #3(Au-Cu): treated (see below) and annealed 30 hrs. at 320°C. Specimen #3 treated and measured: quenched from 800°C, k = 0.193 at 86 K; quenched from 800°C, annealed 22 hrs. at 360°C, k = 1.28 at 85 K; requenched from 800°C, k = 0.23 at 83 K; then #3 treated and measured. Another specimen of 4.66 Cu also measured.	Same as above.	Same as above.
G.R.-1(Au-Pd)	Heraeus; 91.2 Au, 8.8 Pd.	Tempered at 800°C for 2 hrs. Another specimen of 83 Au-17 Pd composition annealed 2 hrs. at 800°C; approx. same curve as G.R.-Ag + 25 Au.	Same as above.	Same as above.
W.W.E.-1(Au-Fe)	0.13 (atomic) Fe; RRR(22) = 2.90.	Vacuum cast; homogenized; swaged; annealed 15 hrs. at 700°C. Graph of lattice and electronic thermal conductivity.	A-1; B-1; C-1; D-4(2); E-5; F-4; G-2; O-3; P-2; Q-2.	G.K. White, S.B. Woods, and M.T. Elford (1959); see also G.K. White (1960).

GOLD ALLOYS (cont'd)

(See FIGURES 45a and 45b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
B.K.-1(Au-Pt), 2(Au-Pt), 1(Au-Cr), 2(Au-Cr)	#1(Au-Pt): Garrett, Davidson and Matthey; 0.7(atomic) Pt; RRR(20) = 3.80. #2(Au-Pt): Garrett, Davidson, and Matthey; 1.6 Pt; RRR(20) = 2.12. #1(Au-Cr): Sigmund Cohn; 0.65 Cr. #2(Au-Cr): Sigmund Cohn, and Garrett, Davidson and Matthey; 6.2 Cr; RRR(20) = 1.2.	#1(Au-Pt): homogenized at 1050°C; drawn (80%); annealed in vacuum 4 hrs. at 1050°C. #2(Au-Pt): received "as drawn"; annealed in vacuum 4 hrs. at 700°C; annealed again 4 hrs. at 1050°C. #1(Au-Cr): specimen #2(Au-Cr) was diluted with pure Au by Garrett, Davidson, and Matthey; annealed in vacuum 4 hrs. at 500°C; annealed again 4 hrs. at 1050°C. #2(Au-Cr): annealed in helium atmosphere 12 hrs. at 200°C; annealed again 12 hrs. at 500°C. Specimen of Au-1.8 Pt also measured with results 2% higher than #2(Au-Pt) at high temperatures. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-4(2); E-1, 5; F-4; G-2; L-1; M-2; O-3; P-2, 3, 6; Q-2, 3, 4; S-1.	J.A. Birch, W.R. G. Kemp, P.G. Klemens, and R. J. Tainsh (1959); see also Kemp and Klemens (1960) and Birch, Kemp, and Klemens (1958).
P.B.G.-1(Au-Co)	Sigmund Cohn; 2.1(Atomic) Co.	Thermocouple alloy; hard-drawn. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-1(8); E-1; F-3; G-2; L-1; N-5; P-2, 3; S-1, 5.	R.L. Powell, M. D. Bunch, and E.F. Gibson (1960).
J.-1(Au-Sn), 2(Au-Sn), 3(Au-Sn), 4(Au-Sn)	Prepared from Johnson, Matthey "spec-pure" Au and "spec-pure" Sn. #1 - #4 (Au-Sn): 50.06(atomic) Sn.	Oriented single crystals cut from large crystal grown from seed; annealed 3 days at 290°C; quenched in ice-water; contained few globular inclusions of a second phase. Rod axis inclined: #1 - 90°, along [100] direction; #2 - 0°, along [001] direction; #3 - 60°; #4 - 20°.	A-1; B-1; C-1; D-4(2); E-1, 5; F-4; G-2; N-4; S-1, 2, 4, 5.	J.-P. Jan, W.P. Pearson, A. Kjekshus, and S.B. Woods (1963).
D.-1(Au-Co), 2(Au-Co), 3(Au-Co), 4(Au-Co)	#1(Au-Co): Johnson, Matthey; 0.34(atomic) Co. #2(Au-Co): 1 Co. #3(Au-Co): 2 Co. #4 (Au-Co): 4 Co.	Annealed 24 hrs. at 800°C.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; P-2, 3; Q-1.	B. Dreyfus, A. Lacaze, P. Thomas, and L. Weil (1963).
B.B.H.-1(Au-Fe)	Prepared with spectroscopically pure Au; 0.03(atomic) Fe; RRR(27) = 9.0.	Annealed; probably strained during mounting.	A-1; B-1; C-1; D-1(3); E-5; F-4; G-2; L-1; M-2; Q-1; S-1, 2, 5.	R. Berman, J.C. F. Brock, and D.J. Huntley (1964).

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GOLD ALLOYS (cont'd)
(See FIGURES 45a and 45b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
B.H.-1(Au-Pt), 1(quenched), 2(Au-Pt)	#1(Au-Pt): Engelhard; prepared from 99.999 pure Au and pure Pt; 0.11(atomic) Pt. #2(Au-Pt): Cominco American; prepared from 99.9999 pure Au and 99.999 pure Pt; 1.02 Pt.	Homogenized 24 hrs. at 750°C. #1(Au-Pt): annealed 60 hrs. at room temperature and 40 hrs. at 43°C. #1(quenched): specimen #1 quenched from 1000°C. #2(Au-Pt): annealed 90 hrs. at room temperature. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-1(2); E-2; F-4; G-2; L-1; M-2; P-2, 11; Q-3.	C. van Baarle and R.P. Huebener (1968).
C.R.-1(Au-Ag), 2(Au-Ag), 3(Au-Ag)	Cambridge Metals Research; prepared from 6N Ag and Au. #1: 0.15(atomic) Ag; RRR = 40.2. #2: 2.4 Ag; RRR = 3.50. #3: 21.0 Ag; RRR = 1.34.	Drawn, etched, washed in distilled water and alcohol, dried, sealed into quartz capsules with 1/3 atmosphere of oxygen, annealed 72 hrs. at 900°C. Other specimens with concentration of 0.37(atomic)%, 0.85, 1.9, 4.1, and 7.8 Ag also measured, with intermediate results. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-2, 3; F-4; G-2; L-1; M-2; N-1; O-3; P-1; Q-1; S-2.	R.S. Crisp and J. Rungis (1970).
G.R.-1, 2, 3 (AuFe)	Stock metal 99.999% pure (RRR = 536) #1 - 0.0091 (atomic)Fe; #2 - 0.46 Fe; #3 - 0.98 Fe. Another specimen with 0.0273 Fe has values between 1.3 and 4 K within 3% of curve B.B.H.-1(Au-Fe) on Figure 45b.	Cold-rolled and drawn wires. Annealed in vacuum for 36 hours at 600°C. Graphs of electronic thermal resistivity, lattice conductivity, and Lorenz ratio.	A-1; B-1; C-1; D-3(2); E-5; G-2; L-1, 2; M-2, 6; N-6; P-7, 12; Q-1; S-1, 5.	P.L. Garbarino and C.A. Reynolds (1971).

ZINC ALLOYS

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Balance Zn, 0.85-1.25 Cu, 0.15 Pb, 0.04 Cd, 0.015 Fe, 0.006-0.016 Mg, 0.01 Al and Sn.	Zilloy 15; k = 1.0	. . . . .	Alloy Digest (1952-68)
. . . . .	Balance Zn, 0.85-1.25 Cu, 0.10 Pb, 0.012 Fe, 0.005 Cd, 0.001 Al and Sn.	Zilloy 40; k = 1.0 with grain.	. . . . .	Same as above.
. . . . .	Balance Zn, 3.5-4.3 Al, 0.15 Cu, 0.100 Fe, 0.03-0.08 Mg, 0.007 Pb, 0.005 Cd and Sn.	Zamak-3; similar to ASTM B86 alloy XXIII, SAE 903, and AG40A; k = 1.1.	. . . . .	Same as above.
. . . . .	Balance Zn, 3.5-4.3 Al, 0.75-1.25 Cu, 0.100 Fe, 0.03-0.06 Mg, 0.007 Pb, 0.005 Cd and Sn.	Zamak-5; equivalent to ASTM B86 alloy XXV, SAE 925, and AC41A; k = 1.1.	. . . . .	Same as above.
. . . . .	Balance Zn, 3.50-4.50 Zn, 2.50-3.50 Cu, 0.100 Fe, 0.02-0.10 Mg, 0.007 Pb, 0.005 Cd and Sn.	No. 2 Die Metal; equivalent to ASTM B86 alloy XXI, SAE 921, Mazak 2, Gomak 2, and Zamak 2; k = 2.5.	. . . . .	Same as above.
. . . . .	Balance Zn, 3.9-4.3 Al, 0.10 Cu, 0.050 Fe, 0.005-0.020 Mg and Ni, 0.0020 Cd and Pb, 0.0010 Sn.	Zamak 7; k = 1.1.	. . . . .	Same as above.
. . . . .	Balance Zn, 0.08 Pb.	Commercial rolled zinc; k = 1.08 with grain.	. . . . .	Metals Handbook (1961).
. . . . .	Balance Zn, 0.8 Cu, 0.15 Ti.	Zn-Cu-Ti alloy; k = 1.1 with grain.	. . . . .	Same as above.

CADMIUM ALLOYS
(See FIGURE 51a)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
E.G.-1-CdSb, 2-CdSb.	Kahlbaum. #1 (CdSb): 66.7 (weight) Cd, 33.3 Sb. #2 (CdSb): 50 Cd, 50 Sb.	. . . . .	A-1; B-1; C-1; D-1(2); F-4; G-3; L-1; M-2; S-1, 2, 5.	A. Eucken and G. Gehlhoff (1912).

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MERCURY ALLOYS

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	Measured ratio of normal and superconducting states. See also Mercury Figure and Table under "Elements" for Hg + Cd and Hg + In.	. . . . .	J. K. Hulm (1950)

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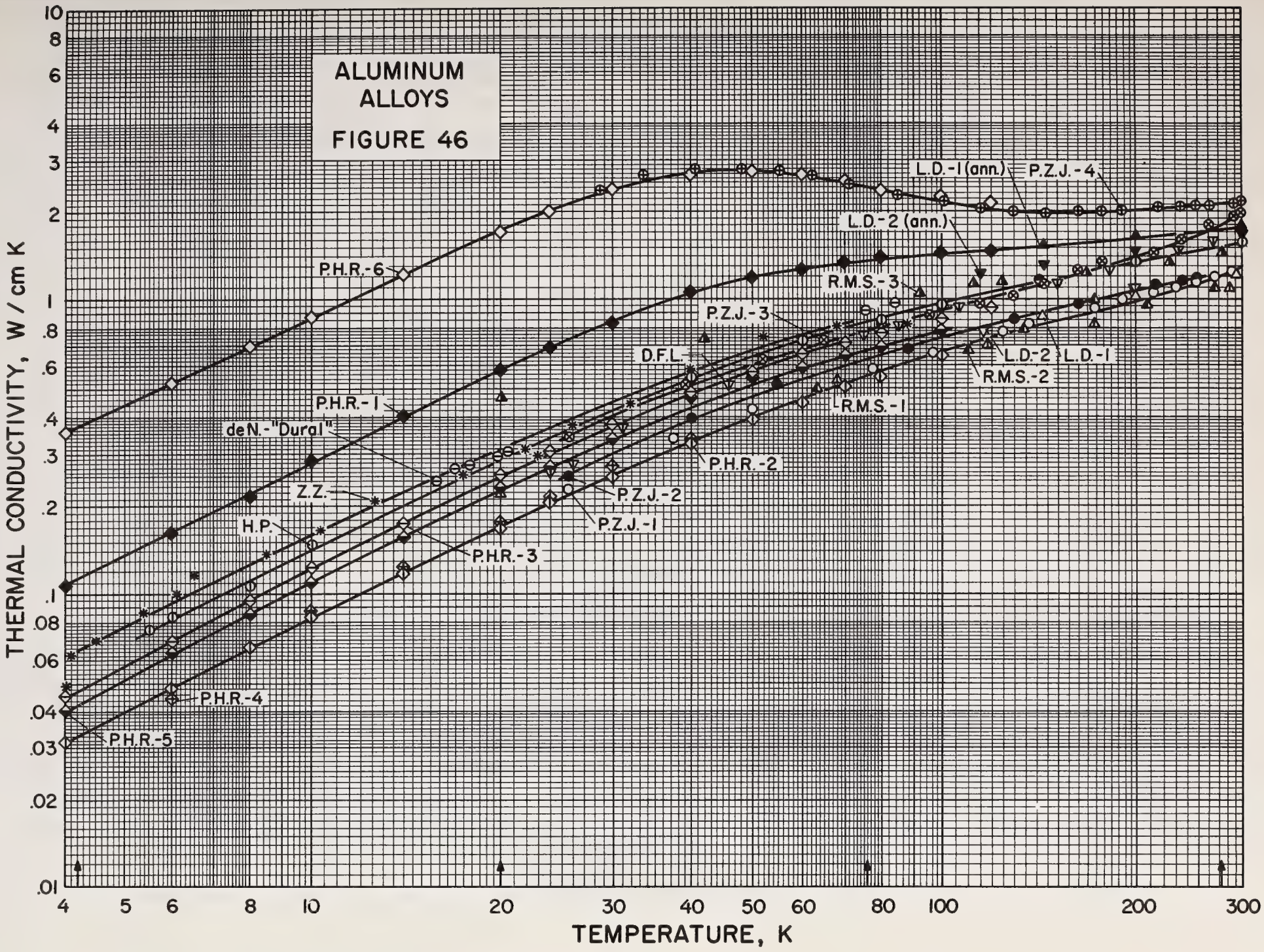
ALUMINUM ALLOYS
FIGURE 46
THERMAL CONDUCTIVITY, W / cm K
TEMPERATURE, K
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
.01
4
5
6
8
10
20
30
40
50
60
80
100
200
300
L.D.-1 (ann.)
P.Z.J.-4
L.D.-2 (ann.)
P.H.R.-6
R.M.S.-3
P.Z.J.-3
D.F.L.
L.D.-2
L.D.-1
R.M.S.-2
R.M.S.-1
P.H.R.-1
deN.-"Dural"
P.H.R.-2
Z.Z.
P.Z.J.-2
H.P.
P.Z.J.-1
P.H.R.-3
P.H.R.-4
P.H.R.-5

ALUMINUM ALLOYS
(See FIGURE 46)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	99 Aℓ, 0.5 Fe, 0.4 Cu.	k = 2.01 at 18°C. Specific density of 2.71 at 18°C. Same specimen was drawn; k = 1.99.	A-4; B-1; C-2, 3; D-1(3); E-1; F-4; G-3; S-1, 2, 3, 5.	W. Jaeger and H. Diesselhorst (1900).
. . . . .	Commercial Aℓ.	k = 1.93 at 273K; k = 1.90 at 85K; k = 1.55 at 20.7K.	A-1; B-1; C-1; D-1(2); E-1; F-5; G-3; L-1; M-1; S-1, 5.	R. Schott (1916).
. . . . .	. . . . .	The following specimens were measured at 27° C. (1) indicates specimens were chill-cast in iron mold, then annealed for 30 minutes at 450°C. (2) indicates specimens chill-cast in iron mold, annealed, then heated for 30 min at about 500°C, quenched in water, and later aged two weeks. (3) indicates specimens chill-cast in iron mold, forged, then cold-drawn to 60% original diameter, later annealed 30 min at 500 °C.	A-4; B-1; C-2; D-1(3); F-5; G-3.	H. Masumoto (1925).
. . . . .	12.2 Cu, 0.6 Fe, 0.3 Si.	(1) Cast, k = 1.24; annealed, k = 1.48.	Same as above.	Same as above.
. . . . .	12.2 Cu, 1 Mn, 0.6 Fe, 0.2 Si.	(1) Cast, k = 0.93; annealed, k = 1.33.	Same as above.	Same as above.
. . . . .	10.5 Cu, 3 Sn, 1 Ni, 0.8 Fe, 0.3 Si.	(1) Cast, k = 1.35; annealed, k = 1.59.	Same as above.	Same as above.
. . . . .	8.4 Cu, 0.7 Fe and Mn, 0.3 Si.	(1) Cast, k = 1.02; annealed, k = 1.35.	Same as above.	Same as above.
. . . . .	8.1 Cu, 0.6 Fe, 0.4 Si.	(1) Cast, k = 1.39; annealed, k = 1.67.	Same as above.	Same as above.
. . . . .	6.9 Cu, 1.2 Sn, 0.7 Fe, 0.3 Si.	(1) Cast, k = 1.47; annealed, k = 1.66.	Same as above.	Same as above.
. . . . .	5.3 Cu, 1.2 Mg, 0.8 Fe, 0.5 Mn and Si.	(1) Cast, k = 1.18; annealed, k = 1.52.	Same as above.	Same as above.
. . . . .	4.3 Cu, 0.9 Fe, 0.6 Mn, 0.4 Mg and Si.	(1) Cast, k = 1.22; annealed, k = 1.52.	Same as above.	Same as above.
. . . . .	2.5 Cu, 1.8 Ni, 0.9 Fe and Mg, 0.4 Si.	(1) Cast, k = 1.44; annealed, k = 1.63.	Same as above.	Same as above.
. . . . .	4.4 Cu, 2.1 Ni, 0.9 Mg, 0.7 Fe, 0.5 Si.	(1) Cast, k = 1.30; annealed, k = 1.47.	Same as above.	Same as above.
. . . . .	6.1 Si, 3.8 Cu, 1.6 Mg, 0.9 Fe, 0.6 Mn.	(1) Cast, k = 1.00; annealed, k = 1.36.	Same as above.	Same as above.
. . . . .	12.0 Zn, 2.7 Cu, 0.6 Fe, 0.4 Si.	(1) Cast, k = 1.32; annealed, k = 1.33.	Same as above.	Same as above.
. . . . .	20.3 Zn, 2.6 Cu, 0.6 Fe, 0.4 Si.	(1) Cast, k = 1.07; annealed, k = 1.08.	Same as above.	Same as above.

ALUMINUM ALLOYS (cont'd)

(See FIGURE 46)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	2.6 Zn, 2.5 Cu, 0.8 Fe, 0.5 Mn, 0.3 Si.	(1) Cast, k = 1.26; annealed, k = 1.45.	A-4; B-1; C-2; D-1(3); F-5; G-3.	H. Masumoto (1925).
. . . . .	1.9 Cu, 1.5 Mg, 1 Fe, 0.1 Si.	(1) Cast, k = 1.57; annealed, k = 1.65.	Same as above.	Same as above.
. . . . .	1.8 Cu, 0.9 Cr and Fe, 0.4 Si.	(1) Cast, k = 1.05; annealed, k = 1.09	Same as above.	Same as above.
. . . . .	1.8 Cu, 1.6 Mg, 1 Ni, 0.6 Fe, 0.3 Si.	(1) Cast, k = 1.48; annealed, k = 1.65.	Same as above.	Same as above.
. . . . .	11.9 Si, 0.8 Fe.	(1) Cast, k = 1.31; annealed, k = 1.78.	Same as above.	Same as above.
. . . . .	0.6 Fe, 0.1 Si.	(1) Cast, k = 1.86; annealed, k = 2.00.	Same as above.	Same as above.
. . . . .	8.1 Cu, 0.6 Fe, 0.4 Si.	(2) Quenched, k = 1.33; aged, k = 1.32.	Same as above.	Same as above.
. . . . .	5.3 Cu, 1.2 Mg, 0.8 Fe, 0.5 Mn and Si.	(2) Quenched, k = 1.23; aged, k = 1.23.	Same as above.	Same as above.
. . . . .	2.5 Cu, 1.8 Ni, 0.9 Fe and Mg, 0.4 Si.	(2) Quenched, k = 1.38; aged, k = 1.33.	Same as above.	Same as above.
. . . . .	6.1 Si, 3.8 Cu, 1.6 Mg, 0.9 Fe, 0.6 Mn.	(2) Quenched, k = 1.16; aged, k = 1.14.	Same as above.	Same as above.
. . . . .	20.3 Zn, 2.6 Cu, 0.6 Fe, 0.4 Si.	(2) Quenched, k = 0.98; aged, k = 0.98.	Same as above.	Same as above.
. . . . .	2.6 Zn, 2.5 Cu, 0.9 Fe, 0.5 Mn, 0.3 Si.	(2) Quenched, k = 1.32.	Same as above.	Same as above.
. . . . .	1.9 Cu, 1.5 Mg, 1 Fe, 0.1 Si.	(2) Quenched, k = 1.59.	Same as above.	Same as above.
. . . . .	1.8 Cu, 1.6 Mg, 1.0 Ni, 0.6 Fe, 0.3 Si.	(2) Quenched, k = 1.45.	Same as above.	Same as above.
. . . . .	5.3 Cu, 1.2 Mg, 0.8 Fe, 0.5 Mn and Si.	(3) Drawn, k = 1.36; annealed, k = 1.60.	Same as above.	Same as above.
. . . . .	4.3 Cu, 0.9 Fe, 0.6 Mg, 0.4 Mn and Si.	(3) Drawn, k = 1.48; annealed, k = 1.73.	Same as above.	Same as above.
. . . . .	11.9 Si, 0.8 Fe.	(3) Drawn, k = 1.73; annealed, k = 1.81.	Same as above.	Same as above.
. . . . .	0.5 Fe, 0.1 Si.	(3) Drawn, k = 2.06; annealed, k = 2.07.	Same as above.	Same as above.
. . . . .	8 Cu.	k = 1.32 at 273 K; k = 0.88 at 87 K.	A-1; B-1; C-1; D-1(2); E-2; F-4; G-3; S-1, 5.	W. Mannchon (1931).
. . . . .	8 Cu.	k = 1.31 at 273 K; k = 0.90 at 87 K.	Same as above.	Same as above.
. . . . .	15 Cu.	k = 1.48 at 273 K; k = 0.90 at 87 K.	Same as above.	Same as above.
. . . . .	8 Mg.	k = 1.00 at 273 K; k = 0.73 at 87 K.	Same as above.	Same as above.
. . . . .	8 Mg.	Thermally treated; k = 1.05 at 273 K; k = 0.77 at 87 K.	Same as above.	Same as above.
. . . . .	12 Mg.	k = 0.77 at 273 K; k = 0.56 at 87 K.	Same as above.	Same as above.
. . . . .	14 Mg.	Thermally treated; k = 0.69 at 273 K; k = 0.44 at 87 K.	Same as above.	Same as above.

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ALUMINUM ALLOYS (cont'd)

(See FIGURE 46)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	20 Si.	"Alusil"; k = 1.59 at 273K; k = 1.2. at 87K.	A-1; B-1; C-1; D-1(2); E-2; F-4; G-3; S-1, 5.	W. Mannchon (1931).
. . . . .	4 Cu, 2 Ni, 1.5 Mg.	"Y alloy"; k = 1.62 at 273K; k = 1.12 at 87K.	Same as above.	Same as above.
. . . . .	4 Cu, 2 Ni, 1.5 Mg.	"Y alloy"; thermally treated; k = 1.53 at 273K; k = 1.38 at 87K.	Same as above.	Same as above.
. . . . .	Mg, Mn, Sb.	K-S Alloy 245; k = 1.07 at 273K; k = 1.00 at 87K.	Same as above.	Same as above.
. . . . .	Mn, Mg, Sb.	K-S Alloy 280; k = 1.00 at 273K; k = 0.80 at 87K.	Same as above.	Same as above.
. . . . .	Mn, Mg, Sb.	K-S Alloy Special; k = 1.39 at 273K; k = 1.14 at 87K.	Same as above.	Same as above.
. . . . .	Cu, Mn, Mg.	Nelson-Kolben 10; k = 1.60 at 273K; k = 1.32 at 87K.	Same as above.	Same as above.
. . . . .	Cu.	Nelson-Kolben Vn 1; k = 1.43 at 273K; k = 1.18 at 87K.	Same as above.	Same as above.
. . . . .	Cu.	Nelson-Kolben; k = 1.59 at 273K; k = 1.30 at 87K.	Same as above.	Same as above.
. . . . .	3-5 Cu, 0.5 Mg.	k = 1.60 at 273K; k = 0.89 at 87K.	Same as above.	Same as above.
. . . . .	. . . . .	The following specimens measured at 25°C. Condition (1a) is chill-cast; (1b) cast in green sand, quenched from high-temperature solution treatment, aged at room temperature only; (1c) reduced, quenched from high-temperature solution treatment, given low-temperature precipitation treatment; (1d) wrought, heated; (1e) same as (1c) without low-temperature precipitation treatment; (1f) sand cast; condition (2): specimen is then annealed at 371°C, cooled to 316°C at 4°C/hr, then furnace cooled.	A-1; B-1; C-1; D-1(3); F-4; G-3; L-1; M-2; S-1.	L.W. Kempf, C.S. Smith, and C.S. Taylor (1937).
. . . . .	13.80 Si, 2.45 Ni, 1.18 Mg, 1.09 Fe, 0.75 Cu.	(1a) k = 1.14; (2) k = 1.36.	Same as above.	Same as above.
. . . . .	10.40 Cu, 1.40 Fe, 0.59 Si, 0.29 Mg.	(1a) k = 1.43; (2) k = 1.76.	Same as above.	Same as above.
. . . . .	3.94 Cu, 2.14 Ni, 1.52 Mg, 0.63 Fe, 0.55 Si.	(1a) k = 1.44; (2) k = 1.68.	Same as above.	Same as above.
. . . . .	4.39 Cu, 0.73 Fe, 0.66 Si.	(1b) k = 1.45; (2) k = 1.89.	Same as above.	Same as above.
. . . . .	5.04 Si, 0.95 Cu, 0.36 Fe, 0.34 Mg.	(1b) k = 1.50; (2) k = 1.90.	Same as above.	Same as above.

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ALUMINUM ALLOYS (cont'd)

(See FIGURE 46)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	3.84 Cu, 1.96 Ni, 1.29 Mg, 0.80 Fe, 0.55 Si.	(1c) k = 1.47; (2) k = 1.87.	A-1; B-1; C-1; D-1(3); F-4; G-3.	L.W. Kempf, C.S. Smith, and C.S. Taylor (1937).
. . . . .	0.91 Si, 0.58 Fe, 0.50 Cu and Mg.	(1c) k = 1.87; (2) k = 2.10.	Same as above.	Same as above.
. . . . .	4.45 Cu, 0.85 Si, 0.76 Mn, 0.50 Fe.	(1d) k = 1.55; (2) k = 1.97.	Same as above.	Same as above.
. . . . .	3.79 Cu, 0.96 Fe, 0.59 Mn, 0.49 Mg, 0.15 Si.	(1e) k = 1.47; (2) k = 1.79.	Same as above.	Same as above.
. . . . .	7.06 Cu, 2.22 Zn, 1.21 Fe, 0.75 Si.	(1f) k = 1.41; (2) k = 1.70.	Same as above.	Same as above.
. . . . .	11.78 Si, 1.06 Mg, 0.92 Ni, 0.84 Cu, 0.76 Fe.	(1c) k = 1.67; (2) k = 1.78.	Same as above.	Same as above.
deN.-"Dural"	94.0 Aℓ, 4.10 Cu, 0.57 Mg, 0.42 Fe.	"Duraluminum"; as stamped; Brinell hardness of 118.	A-1; B-1; C-1; D-2(2); E-5; F-4; G-2; M-1, 2.	J. de Nobel (1951).
P.Z.J.-1, 2, 3, 4	#1: 5.5 Zn, 2.5 Mg, 1.5 Cu, 0.3 Cr, 0.2 Mn. #2: 4.49 Cu, 1.47 Mg, 0.66 Mn, 0.34 Fe, 0.13 Si, 0.02 Ti, 0.01 Cr and Zn. #3: 1.20 Mn, 1.02 Mg, 0.52 Fe, 0.16 Cu, 0.13 Si, 0.02 Cr and Ti. #4: 0.56 Fe and Mg, 0.38 Si, 0.29 Cu, 0.02 Mn, 0.01 Cr and Ti.	#1: 75 S. #2: 24 S. #3: 4 S. #4: J51.	A-1; B-1; C-1; D-1(2); E-1; F-2; G-2; L-1, 2.	R.W. Powers, J.B. Ziegler, and H.L. Johnston (1951 b).
Z.Z.	Balance Aℓ, 4.4 Cu(nominal), 1.5 Mg, 0.6 Mn.	"Duraluminum, D"; not tempered.	A-1; B-1; C-1; D-3(2); E-3, 5; G-3; O-5.	Z. Zavaritskii and A.C. Zeldovich (1956).
L.D.-1, 1(ann), 2, 2(ann)	Aluminum Co. of America.	#1: 2024-T4. #1(ann): heated above 302°C. #2: 7075-T6. #2(ann): heated above 302 °C.	A-6; B-1; C-2; D-1(7); E-1; F-2; G-2; S-1, 3, 6.	C.F. Lucks and H.W. Deem (1958).

ALUMINUM ALLOYS (cont'd)

(See FIGURE 46)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
P.H.R.-1, 2, 3, 4, 5, 6; also see FIGURE 24a	Aluminum Co. of America (except #4: Kaiser Aluminum and Chemical Corp.). #1: 1.23 Mn, 0.48 Fe, 0.15 Si, 0.1 Cu, Ga, and Mg, 0.02 Cr, 0.01 Ti, V, and Zn, 0.001 Bi, Pb, and Zr. #2: 4.58 Cu, 1.70 Mg, 0.1 Ga, Fe, Mn, Si, V, and Zn, 0.05 Cr, 0.01 Sn and Ti, 0.001 Ag, Ca, and Zr. #3: 2.46 Mg, 0.22 Cr, 0.1 Cu, Ga, Fe, Mn, Si, and Zn, 0.01 Ti and V, 0.001 Ca and Zr. #4: 4.44 Mg, 0.7 Mn, 0.1 Cr, Fe, and Si, 0.04 Cu. #5: 3.32 Mg, 0.21 Cr, 0.1 Cu, Fe, Mn, and Si, 0.01 Ti, V, Zn, and Zr, 0.001 Ca and Pb. #6: 0.65 Mg, 0.38 Si, 0.1 Ga, Fe, and Mn, 0.01 Cr, Cu, Ti, V, and Zn, 0.001 Ca and Pb.	#1: alloy 3003-F; turned and drawn; inclusions of Si, $MnAl_6$, $FeAl_3$, and $(MnFe)Al_6$ peritectic. #2: alloy 2024-T4; solution heat-treated, turned and drawn; inclusions of $CuAl_2$ and $MnAl_6$. #3: alloy 5052-O; turned and drawn, annealed in vacuum 1 hr at 350°C; inclusions of $CrAl_7$, Si, $MnAl_6$, and β-phase of (MgAl) with composition of Mg_5Al_8. #4: alloy 5083-O; turned and drawn, annealed in vacuum 1 hr at 350°C; inclusions of β-phase (Mg_5Al_8), $MnAl_6$, Si, Mg_2Si, $CrAl_7$, and (FeMn) Al_6. #5: alloy 5154-O; turned and drawn, annealed in vacuum 1 hr at 350°C; inclusions of β-phase (Mg_5Al_8), $CrAl_7$, $FeAl_3$, and $MnAl_6$. #6: alloy 6063 T-5; precipitation heat-treated, turned down and drawn to a sheet; inclusions of Si, $FeAl_3$, and $MnAl_6$. Average longitudinal grain size of: 0.016 × 0.008, 0.080 × 0.052, 0.056 × 0.032, 0.74 × 0.21, 0.036 × 0.028, and 0.052 × 0.048 mm, respectively. Average transverse grain size of: 0.012, 0.048, 0.04, 0.54 × 0.14, 0.032, and 0.052 mm, respectively. Longitudinal diamond point hardness of: 25, 66, 31, 21, 40, and 29, respectively. Transverse diamond point hardness of: 27, 66, 24, 20, 33, and 30. A specimen of alloy 5086 also measured, with results essentially the same as #4. See ALUMINUM Table under Elements for 1100-O and 1100-F.	A-1; B-1; C-1; D-1(8); E-2; F-3; G-1; L-1, 2; M-1, 2; N-1; P-2, 3; Q-1, 3; S-1, 2, 5.	R.L. Powell, W.J. Hall, and H.M. Roder (1960); see also Hall, Powell, and Roder (1960).

ALUMINUM ALLOYS (cont'd)

(See FIGURE 46)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
R.M.S.-1, 2, 3	#1: balance Al, 5.1 Mg, 0.8 Mn, 0.40 Fe + Si, 0.25 Zn, 0.20 Ti, 0.13 Cr, 0.10 Cu, 0.15 others. #2: balance Al, 5.91 Cu, 0.28 Mn, 0.21 Fe, 0.16 Zr, 0.13 Si, 0.10 V, 0.05 Zn, 0.02 Ti, 0.01 Cr and Mg. #3: balance Al, 4.57 Cu, 0.93 Mn, 0.88 Si, 0.45 Mg, 0.44 Fe, 0.06 Zn, 0.04 Ti, 0.02 Cr.	#1: 5456-H343. #2: 2219-T81. #3: 2014-T6.	A-1; B-1; C-1; D-1(3); E-8; F-2; G-3.	B.L. Rhodes, C.E. Moeller, and H.J. Sauer (1965).
D.F.L.	4.2-5 Zn, 0.9-1.5 Mg, 0.4 Fe, 0.3 Si, 0.2 Mn, 0.15-0.35 Cr, 0.1 Cu and Ti, 0.05-0.25 Zr.	AZ5G; thermal soak 30 min at 450-480°C; aged 24 hrs at 100°C, and 24 hrs at 120°C; annealed after formed several hrs at 400-450°C, followed by slow furnace cool at rate of 10-20°C/hr to 225°C; density at 20°C of 2.79-2.80 g/cm^3.	A-1; B-1; C-1; D-1(2); E-1, 8; F-2; G-3; S-6.	R. Develay, A. Faure, S. Lehongre, D. Mugnier, and D. Schroeter (1967).
H.P.	Balance Al, 3.6(weight) Zn, 2.55 Mg, 0.23 Mn, 0.20 Cr, <0.1 Fe, Cu, Fe, Si, Ti; RRR(22) = 2.71.	7039-T61; fcc structure; Rockwell hardness of B-75; average grain size of 0.005 mm (10:1 elongation with specimen length).	A-1; B-1; C-1; D-1(8); E-1, 2, 3; F-1; G-1; L-1; M-1; N-1, 6; O-3; P-2, 4, 6; S-1, 2, 5.	J.G. Hust and R. L. Powell (1969).
		All values below are at room temperature.		
		CASTING ALLOYS		
. . . . .	Balance Al, 1.5-2.0 Cu, 0.7-1.4 Mn.	Adaptaloy; k = 1.0.	. . . . .	Alloy Digest (1952-68).
. . . . .	Balance Al, 10.0-13.0 Si, 0.7 Fe, 0.5 Mn, 0.4 Cu, 0.2 Ti and Zn, 0.1 Ni and Pb, 0.05 Sn.	Alar 00.12; equivalent to ASTM B179 - S.12A and SAE 30 5; k = 1.5.	. . . . .	Same as above.
. . . . .	Balance Al, 4.5-6.0 Si, 0.6 Fe, 0.5 Mn, 0.10 Mg, 0.1 Cu, Ni, Pb, and Zn, 0.05 Sn.	Alar 00.5; equivalent to ASTM B26 alloy S5A and S5B, and B108 alloy S5A and S5B, and SAE 35 and 304; k = 1.4.	. . . . .	Same as above.

ALUMINUM ALLOYS (cont'd)

(See FIGURE 46)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Balance Al, 7.5-9.5 Si, 3.0-4.0 Cu, 0.60 Fe, 0.10 Mn and Zn, 0.05 Mg, 0.15 others total.	Alcan 143; equivalent to Aluminum A380, ASTM B179-SC84A and B, and SAE 306 and 308; k = 1.1.	. . . . .	Alloy Digest (1952-68).
. . . . .	Balance Al, 8.5-10.5 Si, 2.0-4.0 Cu, 1.2 Fe, 0.50-1.5 Mg and Ni, 0.50 Mn and Zn, 0.20 Ti.	Alcan A143; equivalent to SAE 332; k = 1.0.	. . . . .	Same as above.
. . . . .	Balance Al, 11.0-13.0 Si, 2.0-3.0 Ni, 0.90-1.3 Mg, 0.6 Fe, 0.50-1.5 Cu, 0.20 Ti, 0.10 others total.	Alcan 162; equivalent to ASTM alloy SN122A, SAE 321, and Aluminum A132; k = 1.2.	. . . . .	Same as above.
. . . . .	Balance Al, 11.5-13.0 Si, 3.0-4.0 Cu, 0.60-1.2 Fe, 0.10 Mn, 0.15 others total.	Alcan 164; similar to ASTM B85-60 alloy SC 114 A; k = 0.96.	. . . . .	Same as above.
. . . . .	Balance Al, 6.5-8.0 Cu, 1.0-3.0 Si, 0.95-1.5 Fe, 0.50 Mn, 0.30 Mg, 0.20 Ni and Ti, 0.10 Zn, 0.20 others total.	Alcan 236; Aluminum 236; k = 1.1.	. . . . .	Same as above.
. . . . .	Balance Al, 3.5-4.5 Mg, 0.40 Fe, 0.35-0.65 Si, 0.20 Ti, 0.05 Cu and Mn, 0.15 others total.	Alcan A320; equivalent to Aluminum F214; k = 1.0.	. . . . .	Same as above.
. . . . .	Balance Al, 9.5-10.6 Mg, 0.30 Fe, 0.20 Si, 0.10 Cu, Mn, and Ti, 0.15 others total.	Alcan 350; equivalent to ASTM B179 G10A and B26 G10A; T4 temper, k = 0.88.	. . . . .	Same as above.
. . . . .	Balance Al, 6.0-7.0 Zn, 0.65-0.80 Mg, 0.35-0.65 Cu, 0.30-0.40 Fe, 0.20 Ti, 0.15 Si, 0.05 Mn, 0.15 others total.	Alcan 432; equivalent to ASTM B179 alloy ZG 61 B and SAE 313 (J-453); k = 1.4.	. . . . .	Same as above.
. . . . .	Balance Al, 5.50-7.00 Si, 3.00-4.00 Cu, 1.00 Fe and Zn, 0.50 Mn, 0.30 Ni, 0.15 Mg.	Allcast 60; k = 1.1.	. . . . .	Same as above.
. . . . .	Balance Al, 11.0-13.0 Si, 1.3 Fe, 0.6 Cu, 0.5 Ni and Zn, 0.3 Mn.	Alsiloy No.1; equivalent to ASTM B179 alloy S 12 A and B85 alloy S 12 A, and SAE 305; k = 1.2.	. . . . .	Same as above.
. . . . .	Balance Al, 4.00-5.00 Cu, 0.7 Mn, 0.3 Fe and Si, 0.20-0.50 Ti, 0.03 Mg.	Alufont-3; equivalent to ASTM B26 alloy C4A and SAE 38; k = 1.4.	. . . . .	Same as above.

ALUMINUM ALLOYS (cont'd)

(See FIGURE 46)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Balance Al, 11.0-13.0 Si, 2.0 Fe, 0.6 Cu, 0.50 Ni and Zn, 0.35 Mn, 0.15 Sn, 0.10 Mg, 0.25 others total.	Aluminum 13; equivalent to ASTM B85 alloy S 12 B and B179 - S 12 A and B, and SAE 305; k = 1.5.	. . . . .	Alloy Digest (1952-68).
. . . . .	Balance Al, 5.0-6.0 Si, 4.0-5.0 Cu, 1.0 Fe, 0.50 Zn, 0.20 Ti, 0.10 Mg, 0.03 Mn, 0.50 others total.	Aluminum A108; equivalent to ASTM B108 alloy SC-64A and SAE-330; k = 1.4.	. . . . .	Same as above.
. . . . .	Balance Al, 6.0-8.0 Cu, 2.2 Zn, 1.5 Fe, 1.0 Si, 0.5 Mn, 0.30 Ni, 0.20 Ti, 0.07 Mg, 0.50 others total.	Aluminum 112; annealed, k = 1.5.	. . . . .	Same as above.
. . . . .	Balance Al, 6.0-8.0 Cu, 2.2 Zn, 1.4 Fe, 1.0-3.0 Si, 0.50 Mn, 0.30 Ni, 0.20 Ti, 0.07 Mg, 0.30 others total.	Aluminum 113; equivalent to ASTM B179 alloy CS 72 A and SAE-33; cast, k = 1.2; annealed, k = 1.5.	. . . . .	Same as above.
. . . . .	Balance Al, 6.0-8.0 Cu, 3.0-4.0 Si, 2.5 Zn, 1.5 Fe, 0.50 Mn and Ni, 0.30 Mg, 0.20 Ti, 0.50 others total.	Aluminum C113; equivalent to ASTM B179 alloy CS 72 A and SAE 33; k = 1.1.	. . . . .	Same as above.
. . . . .	Balance Al, 11.0-13.0 Si, 2.0-3.0 Si, 1.3 Fe, 0.7-1.3 Mg, 0.5-1.5 Cu, 0.20 Ti, 0.10 Mn and Zn, 0.15 others total.	Aluminum A132; equivalent to ASTM B108 alloy SN 122 A and SAE 321; condition T 551, k = 1.2.	. . . . .	Same as above.
. . . . .	Balance Al, 9.5-10.5 Cu, 3.5-4.5 Si, 1.5 Fe, 0.5 Mn, Ni, and Zn, 0.2 Ti, 0.15-0.35 Mg, 0.5 others total.	Aluminum 138; equivalent to ASTM B179 alloy CS 104 A and B 108 alloy CS 104 A; k = 1.0.	. . . . .	Same as above.
. . . . .	Balance Al, 4.0-5.0 Cu, 1.2 Si, 1.0 Fe, 0.3 Mn, Ti, and Zn, 0.03 Mg, 0.15 others total.	Aluminum 195; equivalent to ASTM B26 alloy C4A, SAE 38, and AMS-4231; k = 1.4.	. . . . .	Same as above.
. . . . .	Balance Al, 4.0-5.0 Cu, 2.0-3.0 Si, 1.2 Fe, 0.50 Zn, 0.35 Mn, 0.25 Ti, 0.05 Mg, 0.35 others total.	Aluminum B195; equivalent to ASTM B108 alloy CS 42 A and SAE 380; k = 1.3.	. . . . .	Same as above.
. . . . .	Balance Al, 7.0-8.5 Cu, 1.4 Fe, 1.0-1.5 Si, 0.30 Mn, 0.20 Ti and Zn, 0.05 Mg, 0.30 others total.	Aluminum 21 ; equivalent to ASTM B26 C1. CS21 and SAE 36; k = 1.2.	. . . . .	Same as above.

ALUMINUM ALLOYS (cont'd)

(See FIGURE 46)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Balance Al, 3.5-4.5 Mg, 0.40 Fe, 0.30 Mn and Si, 0.20 Ti, 0.10 Cu and Zn, 0.15 others total.	Aluminum 214; equivalent to ASTM B26 alloy G4A and SAE 320; k = 1.4.	. . . . .	Alloy Digest (1952-68).
. . . . .	Balance Al, 3.5-4.5 Mg, 1.4-2.2 Si, 0.8 Mn, 0.6 Fe, 0.3 Cu and Zn, 0.2 Cr and Ti, 0.05 others each.	Aluminum B214; equivalent to ASTM B26 alloy GS 42 A and B108 alloy GS 42 A; k = 1.5.	. . . . .	Same as above.
. . . . .	Balance Al, 7.5-8.5 Mg, 1.8 Fe, 0.3 Mn and Si, 0.2 Cu.	Aluminum 218; k = 0.96.	. . . . .	Same as above.
. . . . .	Balance Al, 9.5-10.6 Mg, 0.30 Fe, 0.20 Cu and Si, 0.10 Mn and Zn, 0.15 others total.	Aluminum 220; equivalent to ASTM B26 alloy G10A and B179 alloy G10A, and SAE 324; k = 0.88.	. . . . .	Same as above.
. . . . .	Balance Al, 5.5-7.0 Si, 3.0-4.5 Cu, 1.2 Fe, 1.0 Zn, 0.8 Mn, 0.50 Mg, 0.5 Ni, 0.20 Ti, 0.50 others total.	Aluminum 319; equivalent to ASTM B108 alloy SC8 and B26 alloy SC64A, and SAE 329; k = 1.1.	. . . . .	Same as above.
. . . . .	Balance Al, 8.0-10.0 Si, 3.0-4.5 Cu, 1.2 Fe, 1.0 Zn, 0.80 Mn, 0.60 Mg, 0.50 Ni, 0.20 Ti, 0.50 others total.	Aluminum 333; equivalent to ASTM B179 alloy SC84A and SAE 331; condition F-temper, k = 1.0; condition T5 and T6 tempers, k = 1.2; condition T7 temper, k = 1.4.	. . . . .	Same as above.
. . . . .	Balance Al, 9.0-10.0 Si, 2.0 Fe, 0.6 Cu, 0.5 Ni and Zn, 0.4-0.6 Mg, 0.35 Mn, 0.15 Sn, 0.2 others.	Aluminum 360 (Aluminum A360 has 1.3% Fe); equivalent to ASTM B85 alloy SG3 and SG2, and SAE 309; k = 1.5.	. . . . .	Same as above.
. . . . .	Balance Al, 4.5-6.0 Si, 3.0-4.5 Zn, 2.5-3.5 Cu, 0.8 Fe and Mn + Cr, 0.40 Mg, 0.25 Ni, Pb, and Sn, 0.3 others total.	Aluminum 363; k = 0.96.	. . . . .	Same as above.
. . . . .	Balance Al, 7.5-9.5 Si, 0.25-0.40 Cr and Mg, 0.02-0.04 Be.	Aluminum 364; k = 1.2.	. . . . .	Same as above.
. . . . .	Balance Al, 7.5-9.5 Si, 3.0-4.0 Cu, 2.0 Fe, 1.0 Zn, 0.50 Mn and Ni, 0.35 Sn, 0.50 others total.	Aluminum 380 (Aluminum A380 has 1.3 Fe); equivalent to ASTM B85 alloy SC84A and SC84B, and SAE 306 and 308; chill-cast; k = 0.96.	. . . . .	Same as above.
. . . . .	Balance Al, 11.0-13.0 Si, 2.0-4.0 Cu.	Aluminum 384; k = 0.96.	. . . . .	Same as above.

ALUMINUM ALLOYS (cont'd)

(See FIGURE 46)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Balance Al, 6.0-7.0 Zn, 0.60-0.80 Mg, 0.50 Fe, 0.35-0.65 Cu, 0.20 Ti, 0.15 Si, 0.05 Mn, 0.15 others total.	Aluminum A612; equivalent to ASTM B26-52T alloy ZG61B; k = 1.4.	. . . . .	Alloy Digest (1952-68).
. . . . .	Balance Al, 6.0-7.0 Zn, 1.4 Fe, 0.35-0.65 Cu, 0.30 Si, 0.25-0.45 Mg, 0.20 Ti, 0.05 Mn, 0.15 others total.	Aluminum C612; equivalent to ASTM B26 alloy ZG61B; chill cast, k = 1.5.	. . . . .	Same as above.
. . . . .	Balance Al, 9.5-10.5 Si, 1.7-2.3 Cu, 1.0 Fe and Zn, 0.5 Mn and Ni, 0.1 Mg, 0.2 others each.	Apex 28; k = 1.0.	. . . . .	Same as above.
. . . . .	Balance Al, 9.0-10.0 Si, 1.0 Fe, 0.6 Cu, 0.5 Ni and Zn, 0.4-0.6 Mg, 0.3 Mn, 0.2 others each.	Apex 36; equivalent to ASTM alloy SG100A-B and SAE 309; k = 1.0.	. . . . .	Same as above.
. . . . .	Balance Al, 8.5-9.5 Si, 3.0-4.0 Cu, 1.0 Fe and Zn, 0.50 Mn and Ni, 0.10 Mg, 0.30 others each.	Apex 39; equivalent to ASTM alloy SG84 A and B, and SAE 306 and 308; k = 0.96.	. . . . .	Same as above.
. . . . .	Balance Al, 10.5-11.5 Si, 3.0-4.5 Cu, 1.0 Fe and Zn, 0.50 Mn and Ni, 0.10 Mg, 0.30 others each.	Apex 39-11; equivalent to ASTM alloy SC114A and SAE 303; k = 0.38.	. . . . .	Same as above.
. . . . .	Balance Al, 8.5-9.5 Si, 3.0-4.0 Cu, 2.0-3.0 Zn, 1.0 Fe, 0.50 Ni and Mn, 0.10 Mg, 0.30 others each.	Apex Z39; equivalent to ASTM B85 alloy SC84A and SC84B, and SAE 306 and 308; k = 0.92.	. . . . .	Same as above.
. . . . .	Balance Al, 10.5-11.5 Si, 3.0-4.0 Cu, 2.0-3.0 Zn, 1.0 Fe, 0.50 Mn and Ni, 0.10 Mg, 0.30 others each.	Apex Z39-11; die cast, k = 0.84.	. . . . .	Same as above.
. . . . .	Balance Al, 3.5-4.5 Cu, 2.5-3.5 Si, 1.5-2.5 Zn, 1.0 Fe, 0.5 Mn, 0.3 Ni, 0.10 Mg, 0.3 others total.	Apex Z-50; k = 1.1.	. . . . .	Same as above.
. . . . .	Balance Al, 3.6-4.2 Mg, 0.40 Fe, 0.30 Mn and Si, 0.2 Ti, 0.15 others total.	Apex 400; equivalent to ASTM B26 alloy G4A and SAE 320; k = 1.3.	. . . . .	Same as above.

ALUMINUM ALLOYS (cont'd)

(See FIGURE 46)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Balance Al, 7.5-8.5 Mg, 1.3 Fe, 0.35 Mn and Si, 0.15 Ni and Zn, 0.10 others total.	Apex 418; equivalent to ASTM B179 alloy G8A and B85 alloy G8A; k = 0.96.	. . . . .	Alloy Digest (1952-68).
. . . . .	Balance Al, 5.0 Si, 0.5 Mg and Mn.	BA.46; equivalent to ASTM B179 alloy SC51A, B26 alloy SC21, and B108 alloy SC21, and SAE 322; k = 1.5.	. . . . .	Same as above.
. . . . .	Balance Al, 3.5-6.0 Si, 0.5 Mn, 0.3-0.8 Mg.	BA. LM8; equivalent to Aluminum 356, ASTM B26 alloy SG1, B108 alloy SG1, and B179 alloy SG70A, and SAE 323; k = 1.5.	. . . . .	Same as above.
. . . . .	Balance Al, 7.5-9.5 Si, 3.0-4.0 Cu, 1.3 Fe, 1.0 Zn, 0.5 Mn and Ni, 0.3 Sn, 0.1 Mg, 0.5 others total.	Birmal P.83; equivalent to SAE 306 and British BS.1490-LM.24.M; k = 0.96.	. . . . .	Same as above.
. . . . .	Balance Al, 8.5-10.5 Si, 2.0-4.0 Cu, 1.2 Fe, 0.5-1.5 Mg and Ni, 0.5 Mn and Zn, 0.20 Ti, 1.0 others total.	Bohnalite L-4; equivalent to SAE 332; k = 1.1.	. . . . .	Same as above.
. . . . .	Balance Al, 3.25-4.5 Mg, 0.6 Fe and Mn, 0.40 Si, 0.10 Cu and Zn, 0.20 others.	Bohnalite M-4; equivalent to ASTM B26 alloy G4A and SAE 320; k = 1.4.	. . . . .	Same as above.
. . . . .	Balance Al, 5.0-8.0 Si, 2.5-4.5 Cu, 1.2 Fe, 1.0 Zn, 0.8 Mn, 0.5 Mg and Ni, 0.20 Ti.	Bohnalite W-6; equivalent to ASTM B108 alloy SC64B and SAE 326; k = 1.1.	. . . . .	Same as above.
. . . . .	Balance Al, 2.00-3.00 Cu, 1.00-2.00 Ni, 1.00-1.40 Fe and Si, 0.50-1.00 Mg, 0.05-0.30 Ce.	Ceralumin "C"; k = 1.8.	. . . . .	Same as above.
. . . . .	Balance Al, 5.00-5.75 Zn, 1.0 Fe, 0.50-0.65 Mg, 0.40-0.60 Cr, 0.30 Cu and Mn, 0.25 Si, 0.15-0.25 Ti.	Frontier 40-E; k = 0.88.	. . . . .	Same as above.
. . . . .	Balance Al, 7.6-8.6 Si, 0.4-0.6 Mg, 0.4 Fe, 0.2 Cr, Cu, Mn, and Zn, 0.1-0.3 Be, 0.1-0.2 Ti, 0.15 others total.	Tens-50; k = 1.5.	. . . . .	Same as above.
. . . . .	Balance Al, 2.7-3.3 Zn, 1.4-1.8 Mg, 0.8 Fe, 0.4-0.6 Mn, 0.2-0.4 Cr, 0.2 Cu, Si, and Ti, 0.05 Ni.	Ternalloy 5; equivalent to ASTM alloy ZG32A and SAE 311; k = 0.96.	. . . . .	Same as above.

ALUMINUM ALLOYS (cont'd)

(See FIGURE 46)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Balance Al, 3.4-3.9 Zn, 1.6-2.0 Mg, 0.60 Fe, 0.4-0.6 Mn, 0.2-0.4 Cr, 0.20 Cu, Si, and Ti, 0.05 others each.	Ternalloy-6; k = 0.96.	. . . . .	Alloy Digest (1952-68).
		WROUGHT ALLOYS		
. . . . .	Balance Al, 2.2-2.8 Mg, 0.45 Fe and Si, 0.15-0.35 Cr, 0.10 Cu, Mn, and Zn, 0.15 others total.	Alcan 57S; equivalent to ASTM B209 alloy GR 20A and B210 alloy GR20A, and SAE 201; k = 1.4.	. . . . .	Same as above.
. . . . .	99.60 Al, 0.50 Fe, 0.15 Si, 0.10 Cu and Zn, 0.01 Cr, Mg, and Mn, 0.10 others total.	Aluminum EC; condition O-temper, k = 2.6.	. . . . .	Same as above.
. . . . .	Balance Al, 5.0-6.0 Cu, 0.7 Fe, 0.40 Si, 0.30 Zn, 0.20-0.60 Bi and Pb, 0.15 others total.	Aluminum 2011; equivalent to ASTM B211 alloy CP21; k = 1.4.	. . . . .	Same as above.
. . . . .	Balance Al, 3.8-4.9 Cu, 1.2-1.8 Mg, 0.50 Fe and Si, 0.3-0.9 Mn, 0.25 Cr, 0.10 Zn, 0.10 others total.	Aluminum 2024; equivalent to ASTM B209 alloy CG42A, B211, B273, B210, B274, SAE 24 and 210, AMS 4035, 4037, 4088, 4120, and 4152; condition -O, k = 1.9; condition T3, T4, and T36, k = 1.2.	. . . . .	Same as above.
. . . . .	Balance Al, 5.8-6.8 Cu, 0.30 Fe, 0.20-0.40 Mn, 0.20 Si, 0.5-0.15 V and Zr, 0.02 Mg.	Aluminum 2219; k = 1.3.	. . . . .	Same as above.
. . . . .	Balance Al, 1.0-1.5 Mn, 0.8-1.3 Mg, 0.70 Fe, 0.30 Si, 0.2 Cu, 0.10 Zn, 0.15 others total.	Aluminum 3004; equivalent to ASTM B275 alloy MG11A, B178 and B209 alloy MG11A, B210 and B274 MG11A, and SAE 20; k = 1.6.	. . . . .	Same as above.
. . . . .	Balance Al, 1.00-1.80 Mg, 0.40 Si, 0.25 Zn, 0.20 Cu, 0.10 Cr and Mn, 0.070 Fe, 0.15 others total.	Aluminum Alloy 50S; Aluminum 5050; k = 1.9.	. . . . .	Same as above.
. . . . .	Balance Al, 2.2-2.8 Mg, 0.45 Fe + Si, 0.20 Zn, 0.15-0.35 Cr, 0.10 Cu and Mn, 0.15 others total.	Aluminum 5052; equivalent to ASTM B209 and B210 alloy GR1; k = 1.4.	. . . . .	Same as above.

ALUMINUM ALLOYS (cont'd)

(See FIGURE 46)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Balance Al, 4.5-5.6 Mg, 0.40 Fe, 0.30 Si, 0.10 Cu and Zn, 0.05-0.20 Cr and Mn, 0.15 others total.	Aluminum 5056; k = 1.2.	. . . . .	Alloy Digest (1952-68).
. . . . .	Balance Al, 4.0-4.9 Mg, 0.5-1.0 Mn, 0.40 Fe and Si, 0.25 Cr and Zn, 0.15 Ti, 0.10 Cu, 0.15 others total.	Aluminum 5083; k = 1.15.	. . . . .	Same as above.
. . . . .	Balance Al, 3.5-4.5 Mg, 0.50 Fe, 0.40 Si, 0.25 Cr and Zn, 0.2-0.7 Mn, 0.10 Cu, 0.15 others total.	Aluminum 5086; equivalent to ASTM B178-54T alloy GM40A and B209-54T alloy GM40A; k = 1.3.	. . . . .	Same as above.
. . . . .	Balance Al, 4.7-5.5 Mg, 0.50-1.0 Mn, 0.40 Fe + Si, 0.25 Zn, 0.20 Cu and Ti, 0.05-0.20 Cr, 0.15 others total.	Aluminum 5456; equivalent to ASTM B209 57T, B221 57T. and B308 57T; k = 1.2.	. . . . .	Same as above.
. . . . .	Balance Al, 5.1-6.1 Zn, 2.1-2.9 Mg, 1.2-2.0 Cu, 0.70 Fe, 0.50 Si, 0.20 Ti, 0.18-0.40 Cr, 0.10-0.30 Mn.	Aluminum 75 S; Aluminum 7075; k = 1.2.	. . . . .	Same as above.
. . . . .	Balance Al, 4.5-5.5 Mg, 0.6 Fe, 0.25-0.75 Mn, 1.0 others.	Birmabright B.B.5; equivalent to Aluminum 5083 and 5456, and British B.S. 1470/NSb; k = 1.3.	. . . . .	Same as above.
. . . . .	99.5 Al, 0.4 Fe, 0.30 Si, 0.05 Cu and Mn.	Kynal P5; (soft) k = 2.2	. . . . .	Same as above.
. . . . .	99.0 Al, 0.6 Fe, 0.5 Si, 0.1 Cu, 0.05 Mn, 0.03 Zn.	Kynal P10; equivalent to ASTM B221, B273, B211, B247, B178, B209, B285, and SAE 25; k = 2.2.	. . . . .	Same as above.
. . . . .	Balance Al, 4.25 Mg, 0.75 Mn.	Noral B54S; k = 1.3.	. . . . .	Same as above.
		HEAT TREATABLE		
. . . . .	Balance Al, 0.9-1.8 Si, 0.8-1.4 Mg, 0.7-1.2 Cu, 0.60-1.1 Mn, 0.50 Fe, 0.40 Cr, 0.20 Ti, 0.15 others total.	Aluminum 6066; k = 1.7.	. . . . .	Same as above.
. . . . .	Balance Al, 6.8-8.2 Zn, 2.6-3.4 Mg, 1.6-2.6 Cu, 0.18-0.40 Cr.	Aluminum 7001-T6; k = 1.1.	. . . . .	Same as above.

ALUMINUM ALLOYS (cont'd)

(See FIGURE 46)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Balance Aℓ, 6.3-7.3 Zn, 2.4-3.1 Mg, 1.6-2.4 Cu, 0.7 Fe, 0.50 Si, 0.30 Mn, 0.20 Ti, 0.18-0.40 Cr, 0.15 others total.	Aluminum 7178; condition T6 temper, k = 1.2.	. . . . .	Alloy Digest (1952-68).
. . . . .	Balance Aℓ, 5.3 Zn, 2.7 Mg, 0.5 Mn, 0.4 Cu.	Hiduminium RR. 77; equivalent to British D.T.D. 683, 687A, and 693; k = 1.3; condition W, k = 1.8.	. . . . .	Same as above.
. . . . .	Balance Aℓ, 5.2-6.2 Zn, 2.2-3.2 Mg, 0.5 Fe and Si, 0.3-0.7 Cu and Mn.	Impalco 740; equivalent to Aluminum 7075 and British DTD 5024 and 5044; fully heat treated condition; k = 1.3.	. . . . .	Same as above.
. . . . .	Balance Aℓ, 5.0-6.0 Zn, 2.2-3.2 Mg, 0.8-1.4 Cu, 0.5 Fe and Si, 0.3-0.7 Mn.	Impalco 760; equivalent to Aluminum 7075 and British DTD 5064; fully heat treated condition, k = 1.3.	. . . . .	Same as above.
. . . . .	Balance Aℓ, 5.0-7.5 Zn, 2.0-3.0 Mg, 1.0-2.2 Cu, 0.5 Fe and Si, 0.18-0.5 Mn + Cr.	Impalco 770; equivalent to Aluminum 7178 and British DTD 5074; fully heat treated condition, k = 1.3.	. . . . .	Same as above.
		MISCELLANEOUS		
. . . . .	Balance Aℓ, 5.0-6.0 Cu, 0.70 Fe, 0.40 Si, 0.30 Zn, 0.20-0.60 Bi and Pb, 0.15 others total.	Alcan 28S (free cutting); equivalent to ASTM B211 alloy CB60A; k = 1.5.	. . . . .	Same as above.
. . . . .	Balance Aℓ, 0.70-1.30 Si, 0.50 Fe, 0.40-0.80 Mg and Mn, 0.20 Ti, 0.10 Cu, 0.15 others total.	Alcan B51S(extrusion); equivalent to ASTM B221, B235, B241, B308, and B345, and Aluminum 6351; k = 2.14.	. . . . .	Same as above.
. . . . .	Balance Aℓ, 6.5 Sn, 1.0 Cu and Ni.	Aluminum 750(bearing); k = 1.8.	. . . . .	Same as above.
. . . . .	Balance Aℓ, 6.5 Sn, 2.5 Si, 1.0 Cu, 0.5 Ni.	Aluminum A750(bearing); k = 1.7.	. . . . .	Same as above.
. . . . .	Balance Aℓ, 5.5-7.0 Sn, 1.7-2.3 Cu, 0.9-1.5 Ni, 0.6-0.9 Mg.	Aluminum B750(bearing); k = 1.8.	. . . . .	Same as above.
. . . . .	99.6 Aℓ, 0.35 Fe, 0.25 Si, 0.05 Cu and Zn, 0.03 Mg, Mn, and Ti, 0.15 others total.	Aluminum 1060(corrosion resistant); equivalent to ASTM B209, B210, B211, B235, B285, and B345; k = 2.3.	. . . . .	Same as above.

ALUMINUM ALLOYS (cont'd)

(See FIGURE 46)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Balance Al, 3.5-4.5 Cu, 1.7-2.3 Ni, 1.0 Fe, 0.90 Si, 0.45-0.90 Mg, 0.25 Zn, 0.20 Mn, 0.10 Cr, 0.15 others total.	Aluminum 2018(forging); equivalent to ASTM B247 alloy CN 42 C and SAE 270; condition T-61 temper; k = 1.5.	. . . . .	Alloy Digest (1952-68).
. . . . .	Balance Al, 3.5-4.5 Cu, 1.7-2.3 Ni, 1.2-1.8 Mg, 1.0 Fe, 0.9 Si, 0.25 Zn, 0.20 Mn, 0.10 Cr, 0.15 others total.	Aluminum 2218(forging); equivalent to ASTM B247 alloy CN 42 D and SAE 38; k = 1.7.	. . . . .	Same as above.
. . . . .	Balance Al, 0.8 Mg.	Aluminum 5005(non-heat-treatable); k = 2.0.	. . . . .	Same as above.
. . . . .	Balance Al, 3.1-3.9 Mg, 0.45 Fe + Si, 0.20 Ti and Zn, 0.15-0.35 Cr, 0.10 Cu and Mn, 0.15 others total.	Aluminum 5154(non-heat-treatable); equivalent to ASTM alloy GR40A; k = 1.3.	. . . . .	Same as above.
. . . . .	Balance Al, 0.17 Fe, 0.15-0.50 Mn, 0.12 Si, 0.08-1.20 Mg, 0.07 Cu.	Aluminum 5357(non-heat-treatable); k = 1.68.	. . . . .	Same as above.
. . . . .	Balance Al, 2.4-3.0 Mg, 0.50-1.0 Mn, 0.40 Si + Fe, 0.25 Zn, 0.20 Ti, 0.10 Cu, 0.05-0.20 Cr, 0.15 others total.	Aluminum 5454(welding grade); k = 1.34.	. . . . .	Same as above.
. . . . .	Balance Al, 0.8-1.2 Mg, 0.20 Cu, 0.15-0.45 Mn, 0.10 Fe, 0.08 Si, 0.10 others total.	Aluminum 5457(sheet); k = 1.67.	. . . . .	Same as above.
. . . . .	Balance Al, 1.0 Fe, 0.60-1.2 Si, 0.45-0.8 Mg, 0.35 Cu, 0.25 Zn, 0.20 Mn, 0.15 Ti, 0.15 others.	Aluminum 6161(forging); equivalent to ASTM B247-57T alloy SG 11A and SAE 280; condition T6, k = 1.7; condition 0, k = 1.9; condition T4, k = 1.5.	. . . . .	Same as above.
. . . . .	Balance Al, 4.2-5.0 Zn, 1.0-1.8 Mg, 0.35 Fe and Si, 0.20-0.70 Mn, 0.10 Cu, 0.06-0.20 Cr and Zr, 1.15 others total.	Aluminum X7005(age-hardenable); k = 1.7; aged, k = 1.6.	. . . . .	Same as above.
. . . . .	Balance Al, 3.8-4.8 Zn, 2.9-3.7 Mg, 0.40-0.8 Cu, 0.40 Fe, 0.30 Si, 0.10-0.30 Mn, 0.10-0.25 Cr, 0.10 Ti, 0.15 others total.	Aluminum 7079(age-hardenable); k = 1.3.	. . . . .	Same as above.

ALUMINUM ALLOYS (cont'd)

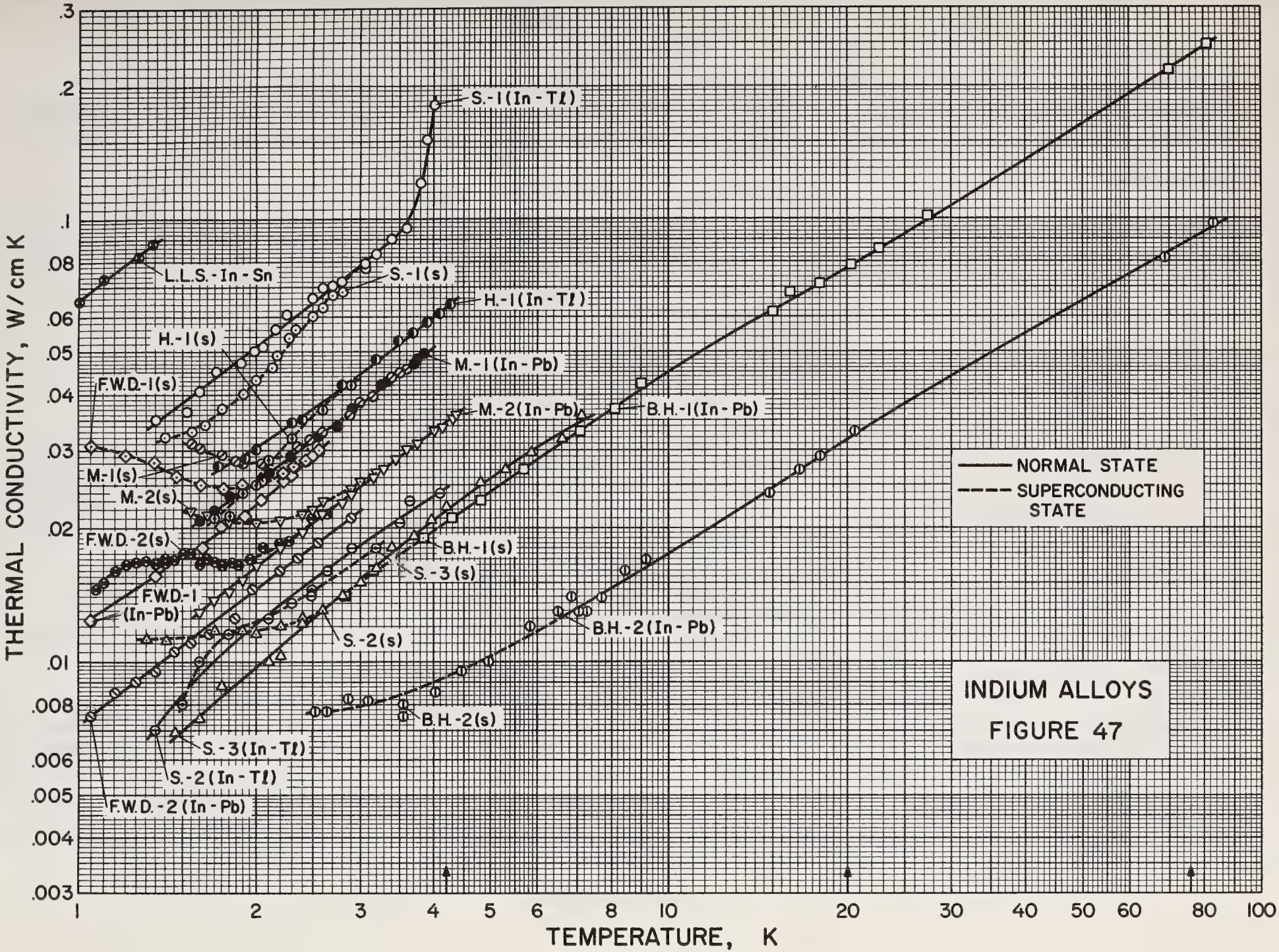
(See FIGURE 46)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Balance Aℓ, 5.2-6.2 Zn, 2.2-3.2 Mg, 0.3-0.7 Cu, 0.3 Mn, 0.08-0.25 Cr.	BA. 703(extrusion); equivalent to Aluminum 7075 and British DTD 5054; k = 1.3.	. . . . .	Alloy Digest (1952-68).
. . . . .	Balance Aℓ, 6.5 Sn, 2.5 Si, 1.0 Cu, 0.5 Ni.	Noral 730(bearing); equivalent to Aluminum A750; k = 1.7.	. . . . .	Same as above.
. . . . .	Balance Aℓ, 4.6-5.1 Zn, 2.0-2.6 Mg, 0.8 Fe, 0.2-0.4 Cr and Mn, 0.2 Cu, Ni, and Si.	Ternalloy 8(precipitation-hardening); k = 0.88.	. . . . .	Same as above.
. . . . .	Balance Aℓ, 4.50 Zn, 1.20 Mn, 1.00 Cu, 0.50 Mg, 0.20 Ti.	Titanite(high strength); k = 0.88.	. . . . .	Same as above.
. . . . .	Balance Aℓ, 0.50 Fe, 0.35-0.8 Mg, 0.3-0.7 Si, 0.10 Cu, 0.06 B, 0.03 Cr and Mn, 0.10 others total.	Aluminum 6101(high conductivity); equivalent to ASTM-B317-64; condition T6, k = 2.2.	. . . . .	Same as above.
. . . . .	> 99.0% Aℓ.	100 Alloy (wrought); commercial; equivalent to ASTM B184, B209, B211, B221, B247, B285, B307, B313, and B316, and SAE 25; k = 2.2	. . . . .	Metals Handbook (1961).
. . . . .	4.4 Cu, 0.8 Mn and Si, 0.4 Mg.	2014 Alloy (wrought); equivalent to ASTM B209, B211, B221, B235, B247, B285, and B308, and SAE 246 and 260; condition O temper, k = 1.9; condition T4, k = 1.2; condition T6, k = 1.5.	. . . . .	Same as above.
. . . . .	1.2 Mn.	3003 Alloy (wrought); equivalent to ASTM B209, B210, B211, B221, B234, B235, B241, B247, B307, B313, B318 and B345, and SAE 29 and 245; condition O temper, k = 1.9; condition H12, k = 1.6; condition H'4, k = 1.6; condition H18, k = 1.5.	. . . . .	Same as above.
. . . . .	12.5 Si, 1.0 Mg, 0.9 Cu and Ni.	4032 Alloy (wrought); equivalent to ASTM B247 and SAE 290; condition O temper, k = 1.5; condition T6, k = 1.4.	. . . . .	Same as above.
. . . . .	1.0 Mg, 0.6 Si, 0.25 Cu and Cr.	6061 Alloy (wrought); equivalent to ASTM B209, B210, B211, B221, B234, B235, B241, B247, B308, B313, and B316, and SAE 244 and 281; condition O temper, k = 1.7; condition T4 and T6, k = 1.5.	. . . . .	Same as above.

ALUMINUM ALLOYS (cont'd)

(See FIGURE 46)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	0.7 Mg, 0.4 Si.	6063 Alloy (wrought); equivalent to ASTM B210, B221, B235 and B241, and SAE 212; condition O temper, k = 2.2; condition T42, k = 1.9; condition T5, k = 2.1; condition T6, k = 2.0.	. . . . .	Metals Handbook (1961).
. . . . .	0.5 Mg and Si.	6101 Alloy (wrought); equivalent to ASTM B317; condition T6, k = 2.2.	. . . . .	Same as above.
. . . . .	12 Si.	A13 Alloy (casting); equivalent to ASTM B85 alloy S12 A and SAE 305; k = 1.2.	. . . . .	Same as above.
. . . . .	5 Si.	43 Alloy (casting); equivalent to B85 alloy S5C, B26 alloy S5A, and B108 alloy S5A; as cast, k = 1.4; annealed, k = 1.6.	. . . . .	Same as above.
. . . . .	4 Cu, 3 Si.	108 Alloy (casting); as cast, k = 1.2; annealed, k = 1.5.	. . . . .	Same as above.
. . . . .	9 Si, 3.5 Cu, 0.8 Mg and Ni.	D132 Alloy (casting); condition T5, k = 1.0.	. . . . .	Same as above.
. . . . .	9.5 Si, 3.0 Cu, 1.0 Mg.	F132 Alloy (casting); equivalent to ASTM B108 alloy SC103A and SAE 332; k = 1.0.	. . . . .	Same as above.
. . . . .	4 Cu, 2 Ni, 1.5 Mg.	142 Alloy (casting); equivalent to ASTM B26 alloy CN42A and B108 alloy CN42A, and SAE 39; condition T21, k = 1.7; condition T571, k = 1.3; condition T77, k = 1.5; condition T61, k = 1.3.	. . . . .	Same as above.
. . . . .	5 Si, 1.3 Cu, 0.5 Mg.	355 Alloy (casting); equivalent to ASTM B26 alloy SC51A and B108 alloy SC51A, and SAE 322; condition T51, k = 1.7; conditions T6 and T61, k = 1.4; condition T7, k = 1.6; condition T6, k = 1.5.	. . . . .	Same as above.
. . . . .	7 Si, 0.3 Mg.	356 Alloy (casting); equivalent to ASTM B26 alloy SG70A and B108 alloy SG70A, and SAE 323; condition T51, k = 1.7; condition T6, sand, k = 1.5; condition T7, k = 1.3; condition T6, permanent mold, k = 1.6.	. . . . .	Same as above.
. . . . .	5.5 Zn, 0.6 Mg, 0.5 Cr, 0.2 Ti.	40 E Alloy (casting); equivalent to ASTM B26 alloy ZG61A and SAE 310; k = 1.4.	. . . . .	Same as above.


THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
.3
.2
.1
.08
.06
.05
.04
.03
.02
.01
.008
.006
.005
.004
.003
1
2
3
4
5
6
8
10
20
30
40
50
60
80
100
S.-1(In-Tl)
L.L.S.-In-Sn
S.-1(s)
H.-1(In-Tl)
H.-1(s)
M.-1(In-Pb)
F.W.D.-1(s)
M.-2(In-Pb)
B.H.-1(In-Pb)
M.-1(s)
M.-2(s)
F.W.D.-2(s)
B.H.-1(s)
S.-3(s)
F.W.D.-1 (In-Pb)
S.-2(s)
B.H.-2(In-Pb)
B.H.-2(s)
S.-3(In-Tl)
S.-2(In-Tl)
F.W.D.-2(In-Pb)
NORMAL STATE
SUPERCONDUCTING STATE
INDIUM ALLOYS
FIGURE 47

INDIUM ALLOYS
(See FIGURE 47)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
B.H.-1(In-Pb), 1(s), 2(In-Pb), 2(s)	#1(In-Pb): 91.4(atomic) In, 8.6 Pb. #2(In-Pb): 50 In, 50 Pb.	#1: T_c = 4.2 K. #2: T_c = 6.54 K. Measured in both the normal (in magnetic fields up to 0.072 T) and superconducting (s) states. Indium and lead form solid solutions in all concentrations.	A-1; B-1; C-1; D-4(2); E-5; F-4; G-3; L-1, 2; M-2; N-2, 3; S-1, 5.	H. Bremmer and W. J. deHaas (1936b).
H.-1(In-Tℓ), 1(s)	90(atomic) In, 10 Tℓ.	Single crystal; very uniform composition. $T_c \cong$ 3.4 K. Measured in both the normal (in magnetic fields up to 0.02 T) and superconducting (s) states. Graph of thermal conductivity as a function of magnetic field.	A-1; B-1; C-1; D-4(2); E-5; F-4; G-2; L-1, 2; M-2; N-2, 3; P-1; Q-1.	J.K. Hulm (1952b).
S.-1(In-Tℓ), 1(s), 2(In-Tℓ), 2(s), 3(In-Tℓ), 3(s)	#1(In-Tℓ): 5(nominal)(atomic) Tℓ. #2(In-Tℓ): 30 Tℓ. #3 (In-Tℓ): 50 Tℓ.	Homogeneous solid solutions. #1: single crystal; T_c = 3.280 K. #2: large grains; T_c = 3.304 K. #3: large grains; T_c = 2.652 K. Measured in both the normal (in longitudinal and transverse magnetic fields up to 0.1 T) and superconducting (s) states. Other specimens of In-15, 20, and 38 Tℓ also measured, with intermediate results. Graph of the ratio of the phonon superconductivity to phonon normal conductivity as a function of reduced temperature. Graph of thermal resistivity as a function of reduced longitudinal and transverse magnetic field.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-2; M-2, 3; N-7; O-5; P-1, 2, 4; Q-1, 3.	R.J. Sladek (1955).
See FIGURE 75	. . . . .	In-Tℓ alloys measured below 1 K.	. . . . .	N.E. Phillips (1955).
. . . . .	In-Bi.	Thermal conductivity in the superconducting state as a function of magnetic field.	. . . . .	L. Dubeck, P. Lindenfeld, E.A. Lynton, and H. Rohrer (1963).
L.L.S.-In-Sn; also see FIGURE 73	American Smelting and Refining; 1 Sn.	Annealed 6 months at 130°C. Measured in longitudinal magnetic field of 0.09 T. Specimen then bent repeatedly at room temperature and remeasured; results lower by about 2%. Also measured below 1 K.	A-1; B-5; C-1; D-3(2); E-5; F-4; G-3; M-2, 3; S-1, 5.	P. Lindenfeld, E.A. Lynton, and R. Soulen (1965).

INDIUM ALLOYS (cont'd)

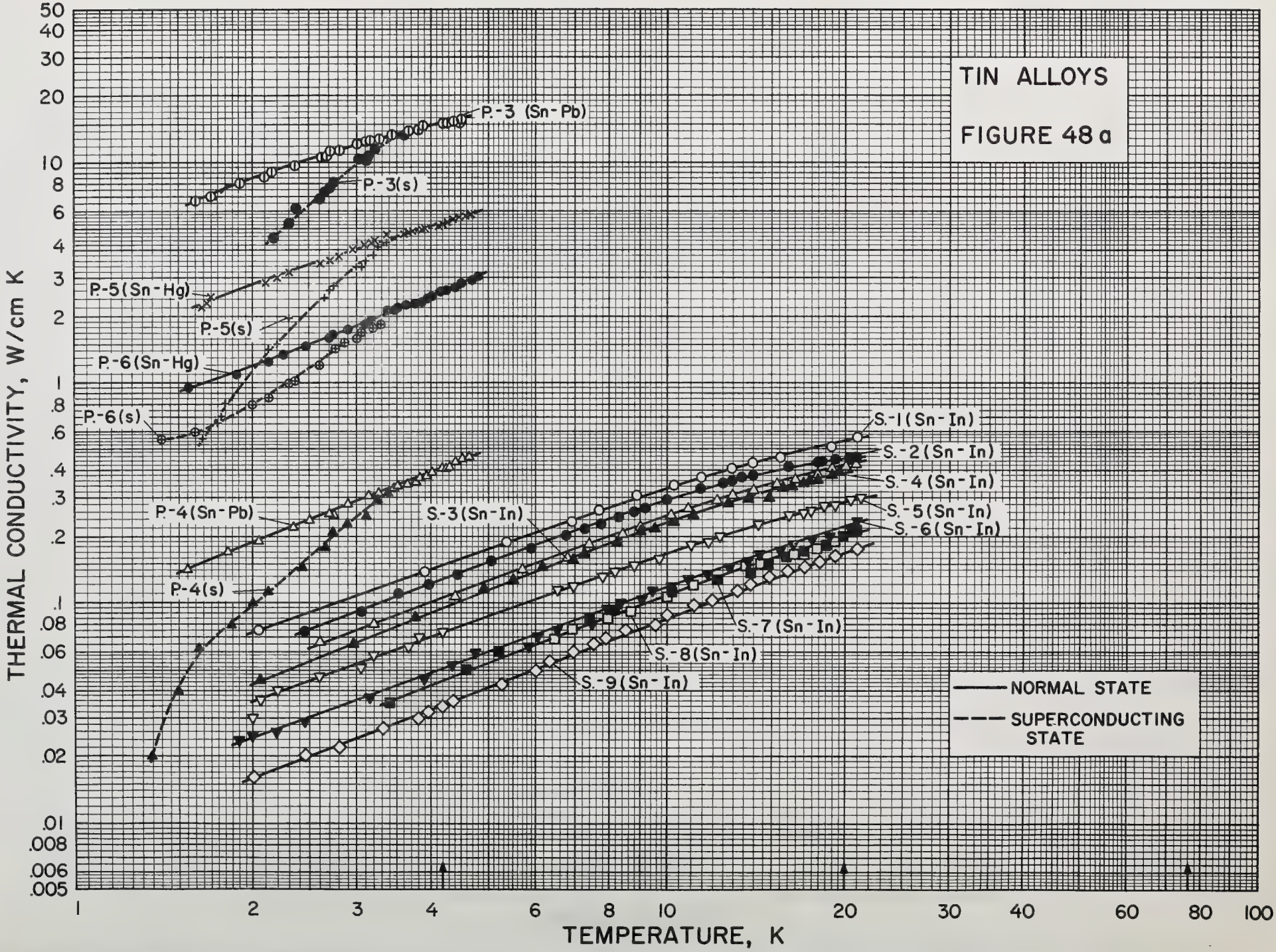
(See FIGURE 47)

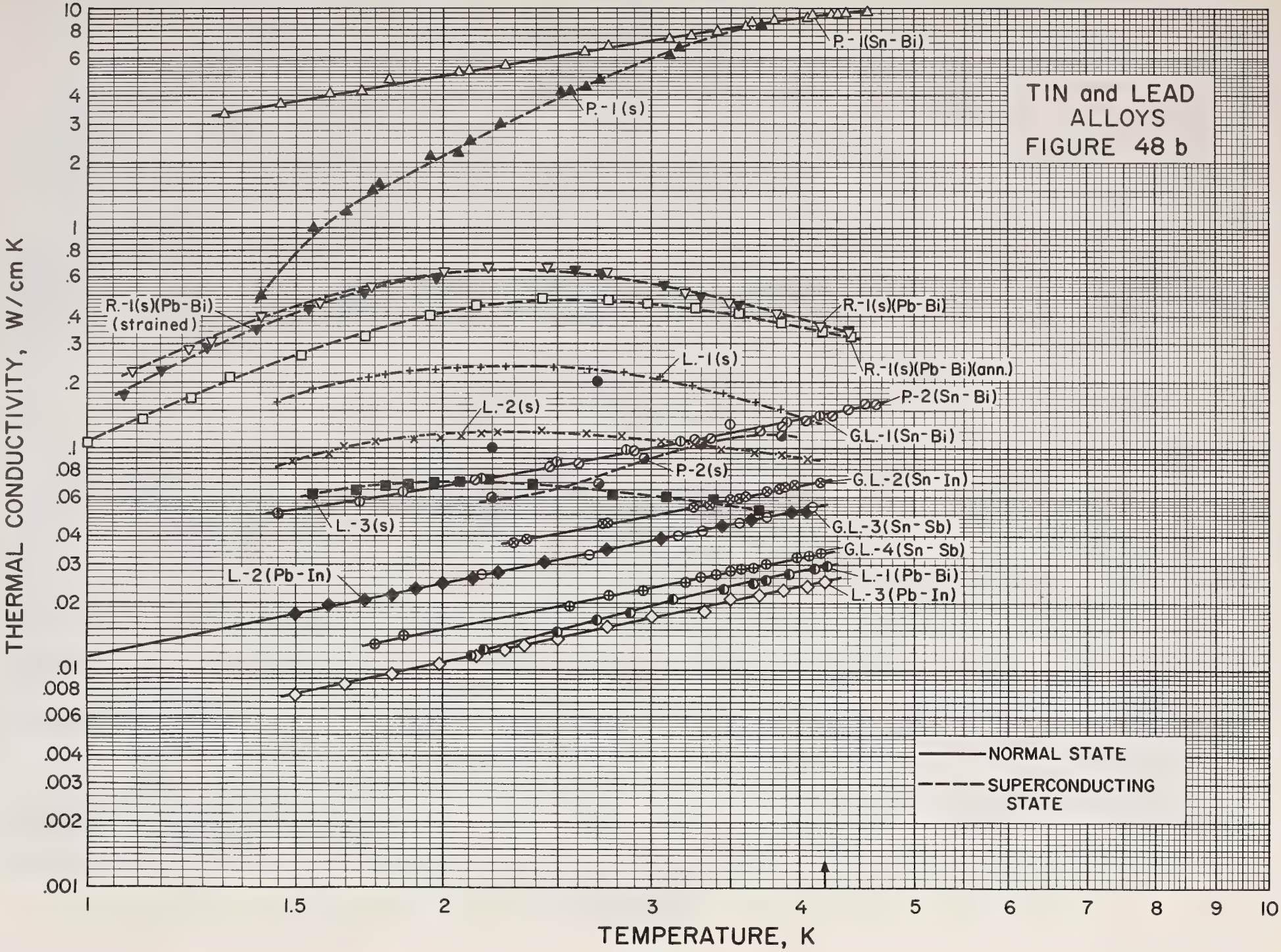
CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	In-Bi and In-Sn.	Graphs of ratio of superconducting to normal thermal conductivity.	. . . . .	P. Lindenfeld and H. Rohrer (1965).
M-1(In-Pb), 1(s), 2(In-Pb), 2(s)	Prepared from Asahi Metal Company 99.999 In and 99.9999 Pb. #1 (In-Pb): 3.90 (atomic) Pb. #2 (In-Pb): 6.40 Pb.	Prepared by melting in vacuum-sealed glass tubes, annealed for 30-60 days at 100°C. #1: T_c = 3.69 K. #2: T_c = 3.87 K. Measured in the normal (in longitudinal magnetic fields up to 0.066 T), mixed, and superconducting (s) states. Another specimen of In-5.0 Pb nominal was measured with intermediate results. Graph of thermal conductivity as a function of magnetic field. Graph of phonon and electronic thermal conductivities in the normal and superconducting states.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-2; M-1,2; N-2,3,5; Q-1.	T. Mamiya (1966).
F.W.D.-(In-Pb), 1(s), 2(In-Pb), 2(s); also see FIGURE 75	#1 (In-Pb): 4.05 (atomic) Pb. #2 (In-Pb): 7.31 Pb.	Measured in both the normal and superconducting (s) states. Also measured below 1 K.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-3; M-1; N-3; O-9; P-2,4; Q-1.	G. T. Fox, M. W. Wolfmeyer, and J. R. Dillinger (1969).
. . . . .	. . . . .	Measured thermal conductivity of 12 In-Pb alloy specimens in both the normal and superconducting states for different orientations; Pb concentration varied between 3 and 8%; temperature range of 1.2-4.2 K; results similar to those for Mamiya (1966).	. . . . .	R. E. Giedd and C. A. Reynolds (1970).
. . . . .	. . . . .	Measured the thermal conductivity of In-Bi alloys in the normal, mixed, and superconducting states in the temperature range 0.3-4.2 K in magnetic fields up to 0.07 T; bismuth concentration varied between 2-4%.	. . . . .	L. V. Del Vecchio and P. Lindenfeld (1970).

THALLIUM ALLOYS

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	66 Tℓ, 34 Pb.	Specimen with "large" crystals; k = 0.22 at 273K; k = 0.13 at 80K. Specimen with "small" crystals: k = 0.23 at 273K; k = 0.14 at 80K.	A-1; B-1; C-1; D-1(2); F-4; G-3; P-4; S-1, 5.	A. Eucken and K. Dittrich (1927).
. . . . .	67(atomic) Tℓ, 33 Pb.	Measurement of relative change of thermal conductivity when alloy became superconductive.	. . . . .	W. J. de Haas and H. Bremmer (1932b).

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	76.8 Si, balance Fe.	Ferrosilicon; k = 0.13 W/cm-K at 19.5°C; k = 0.23 W/cm-K at 14.3°C.	A-4; B-4; C-1, 2; D-1(2); F-4; G-3; M-2.	N.N. Kurnakov and S.D. Rakhmanovski (1937).
. . . . .	71.7 Si, balance Fe.	Ferrosilicon; k = 0.20 W/cm-K at 18.0°C.	Same as above.	Same as above.
. . . . .	73.15 Si, balance Fe.	Ferrosilicon; k = 0.27 W/cm-K at 26°C.	Same as above.	Same as above.


TIN ALLOYS
FIGURE 48 a
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
50
40
30
20
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
.01
.008
.006
.005
1
2
3
4
6
8
10
20
30
40
60
80
100
P.-3 (Sn-Pb)
P.-3(s)
P.-5(Sn-Hg)
P.-5(s)
P.-6(Sn-Hg)
P.-6(s)
P.-4(Sn-Pb)
P.-4(s)
S.-1(Sn-In)
S.-2(Sn-In)
S.-4(Sn-In)
S.-3(Sn-In)
S.-5(Sn-In)
S.-6(Sn-In)
S.-7(Sn-In)
S.-8(Sn-In)
S.-9(Sn-In)
NORMAL STATE
SUPERCONDUCTING STATE


TIN and LEAD ALLOYS
FIGURE 48 b
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
P.-1(Sn-Bi)
P.-1(s)
R.-1(s)(Pb-Bi) (strained)
R.-1(s)(Pb-Bi)
R.-1(s)(Pb-Bi)(ann.)
L.-1(s)
L.-2(s)
P.-2(Sn-Bi)
G.L.-1(Sn-Bi)
P.-2(s)
G.L.-2(Sn-In)
L.-3(s)
G.L.-3(Sn-Sb)
G.L.-4(Sn-Sb)
L.-2(Pb-In)
L.-1(Pb-Bi)
L.-3(Pb-In)
NORMAL STATE
SUPERCONDUCTING STATE

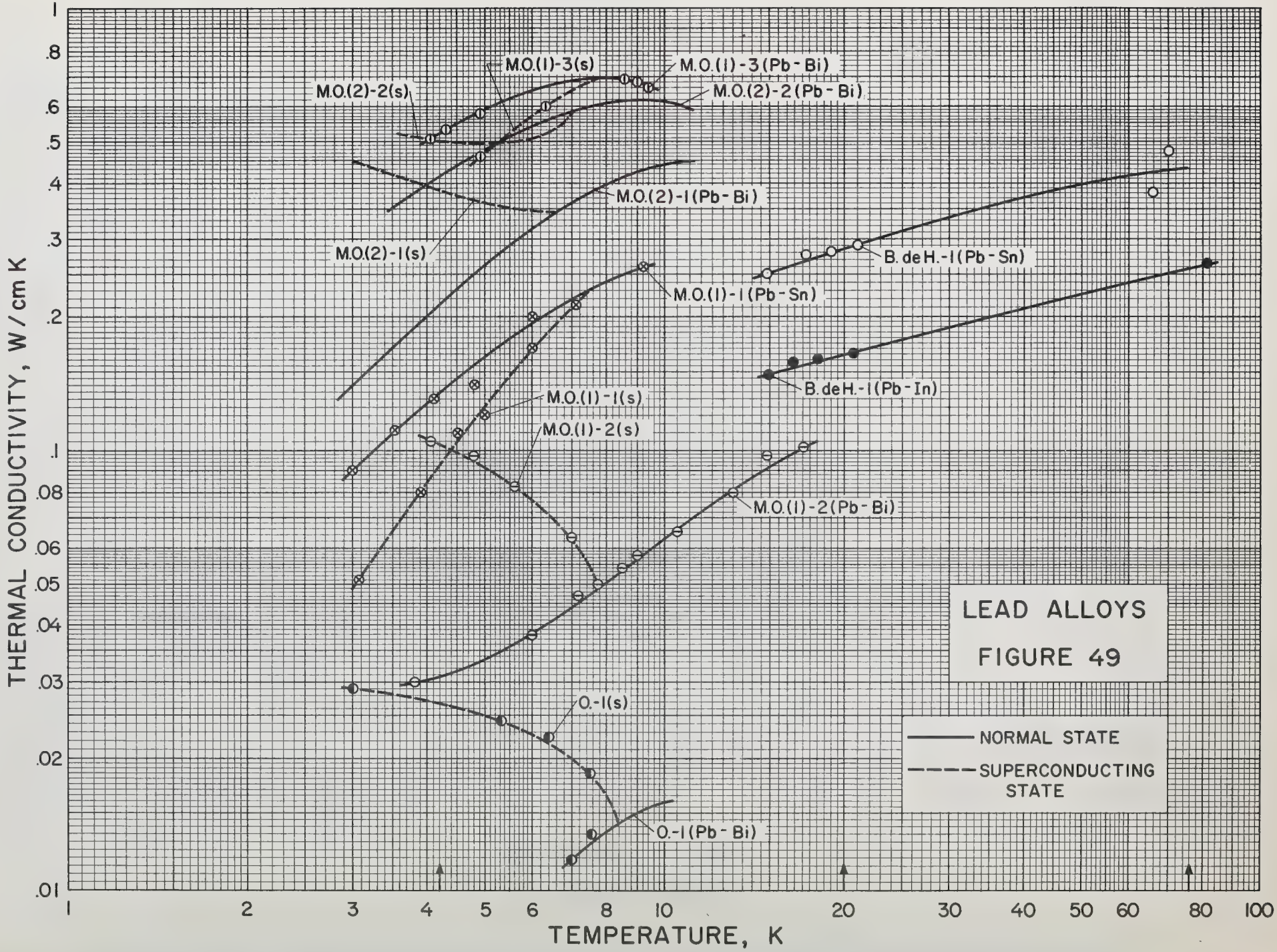
TIN ALLOYS
(See FIGURES 48a and 48b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Up to 4.1 (weight) Hg.	See TIN Table and FIGURES 29b and 29c in "Elements" section.	. . . . .	J.K. Hulm (1949, 1950).
See FIGURE 75	Up to 3 In.	Measured superconducting state below 1 K.	. . . . .	B.B. Goodman (1953).
See FIGURE 75	Sn-3.10 (weight) In.	Measured superconducting state below 1 K.	. . . . .	S.J. Laredo (1955).
S.-1(Sn-In), 2, 3, 4, 5, 6, 7, 8, 9	Prepared from Johnson, Matthey "pure" tin and 'Analar' 99.9 In. #1: 2.02 In. #2: 2.11 In. #3: 2.45 In. #4: 2.84 In. #5: 3.96 In. #6: 4.97 In. #7: 5.65 In. #8: 5.96 In. #9: 8.20 In.	Prepared by melting; homogenized, cast into clean Pyrex tubes under high vacuum, glass dissolved; annealed in vacuum for 30 hrs at 185°C. #1-#3: single crystal, #4: single crystal with 5% of volume consisting of inclusions of foreign orientation; #5-#8: coarse polycrystal with grain size 2-3 mm; #9: fine grained polycrystal. #1: rod axis 90° with the tetragonal axis; #2: rod axis 70° with the tetragonal axis; #3: rod axis 85° with the tetragonal axis; #4: rod axis 78° with the tetragonal axis. Measured in longitudinal magnetic fields of about 0.02 T. Graph of thermal conductivity as a function of transverse and longitudinal magnetic fields.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; L-1, 2; M-2; N-2, 4, 8; O-3; P-4, 6, 9; Q-1; S-1, 5.	C.A. Shiffman (1958); see also K. Mendelssohn and C.A. Shiffman (1960).
G.L.-1(Sn-Bi), 2(Sn-In), 3 (Sn-Sb), 4(Sn-Sb)	#1(Sn-Bi): 1.1 (atomic) Bi; RRR(27) = 16.7. #2(Sn-In): 3.1 In; RRR(27) = 7.70. #3 (Sn-Sb): 2.9 Sb; RRR(27) = 7.50. #4(Sn-Sb): 6. Sb; RRR(27) = 4.29.	Measured in a longitudinal magnetic field of 0.056 T. See TIN Table and FIGURE 29b for specimen of Sn-0.11 Bi.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-2; L-2; M-1, 2; P-3; Q-1, 3; S-1, 5.	M. Garfinkel and P. Lindenfeld (1958).
. . . . .	50.06 (atomic) Sn, balance Au.	See GOLD ALLOYS Table and FIGURES 45a and 45b for results of measurements on Au-50.06 Sn specimens inclined at different angles.	. . . . .	J.-P. Jan, W.P. Pearson, A. Kjekshus, and S.B. Woods (1963).

TIN ALLOYS (cont'd)

(See FIGURES 48a and 48b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
P.-1(Sn-Bi), 1 (s), 2(Sn-Bi), 2(s), 3(Sn-Pb), 3(s), 3(Sn-Pb), 4(s), 5(Sn-Hg), 5(s), 6(Sn-Hg), 6(s).	Prepared with Johnson, Matthey 99.999 Sn and desired impurities. #1(Sn-Bi): 0.0074 (atomic) Bi; RRR = 2180. #2 (Sn-Bi): 0.78 Bi; RRR = 16.7. #3(Sn-Pb): 0.011 Pb; RRR = 2260. #4(Sn-Pb): 0.52 Pb; RRR = 2840. #5(Sn-Hg): 0.011 Hg; RRR = 633. #6(Sn-Hg): 0.23 Hg; RRR = 28.1.	Prepared by melting and extruding; annealed several days at 200°C. Specimens with high impurity concentrations had grains as small as 0.1 mm. #1: T_c = 3.725 K. #2: T_c = 3.700 K. #3: T_c = 3.716 K. #4: T_c = 3.752 K. #5: T_c = 3.718 K. #6: T_c = 3.646 K. Measured in both the normal (in longitudinal magnetic fields) and superconducting (s) states. Three other specimens with intermediate concentrations had intermediate values. Graph of the ratios of the total thermal conductivity and lattice component of the superconducting state to the normal state as a function of reduced temperature.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-2; L-1, 2; M-1, 2; N-3, 7; O-5; P-5; Q-1, 3; S-1, 5.	G. J. Pearson, C. W. Ulbrich, J. E. Gueths, M. A. Mitchell, and C. A. Reynolds (1967).
. . . . .	63Sn, 37 Pb.	Soft solder; equivalent to ASTM B32-58 T grade 60A and 60B; k = 0.50 at 273 K.	. . . . .	Metals Handbook (1961).
. . . . .	92 Sn, 8 Zn.	Tin Foil; k = 0.59 at 273 K.	. . . . .	Same as above.


THERMAL CONDUCTIVITY, W / cm K
TEMPERATURE, K
1
.8
.6
.5
.4
.3
.2
.1
.08
.06
.05
.04
.03
.02
.01
1
2
3
4
5
6
8
10
20
30
40
50
60
80
100
M.O.(1)-3(s)
M.O.(1)-3(Pb-Bi)
M.O.(2)-2(s)
M.O.(2)-2(Pb-Bi)
M.O.(2)-1(Pb-Bi)
M.O.(2)-1(s)
B. deH.-1(Pb-Sn)
M.O.(1)-1(Pb-Sn)
B. deH.-1(Pb-In)
M.O.(1)-1(s)
M.O.(1)-2(s)
M.O.(1)-2(Pb-Bi)
O.-1(s)
O.-1(Pb-Bi)
LEAD ALLOYS
FIGURE 49
NORMAL STATE
SUPERCONDUCTING STATE

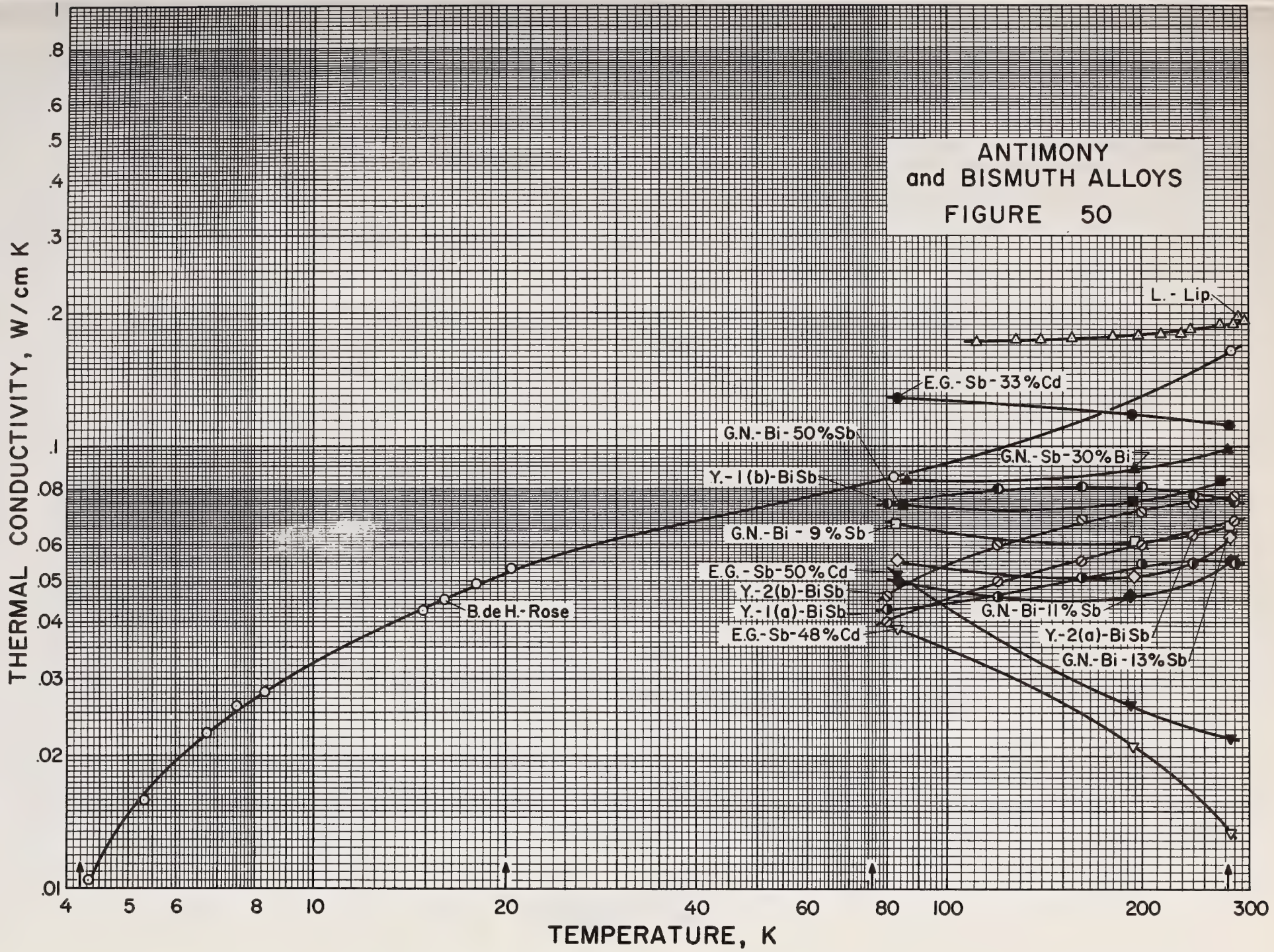
LEAD ALLOYS
(See FIGURES 48b and 49)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
B.deH.-1(Pb-Sn)	56(atomic) Pb, 44 Sn.	Nearly insoluable in one another. A specimen of 99 Pb-1 In also measured; k = 0.149 at 14.8 K; k = 0.165 at 20.4 K; k = 0.26 at 81 K. See Indium Alloys Table and FIGURE 47 for 50 In-50 Pb.	A-1; B-1; C-1; D-4(2); E-5; F-4; G-3; L-1,2; M-2; N-2,3; S-1,5.	H. Bremmer and W.J. de Haas (1936b).
. . . . .	90 Pb, 10 Bi.	Measured conductivity in intermediate state and as a function of magnetic field.	. . . . .	K. Mendelssohn and R.B. Pontius (1937).
M.O.(1)-1(Pb-Sn), 1(s), 2 (Pb-Bi), 2(s), 3(Pb-Bi), 3(s)	#1(Pb-Sn): 70 Pb, 30 Sn. #2 (Pb-Bi): 90 Pb, 10 Bi. #3 (Pb-Bi): 99.9 Pb, 0.1 Bi.	Measured in both the normal and superconducting (s) states. Graph of thermal conductivity as a function of magnetic field up to 0.1 T. Graph of the ratio of the superconducting to normal thermal conductivity as a function of reduced temperature.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-3; M-1; N-2,3; P-1.	K. Mendelssohn and J.L. Olsen (1950a).
M.O.(2)-1(Pb-Bi), 1(s), 2 (Pb-Bi), 2(s)	#1(Pb-Bi): 99.5 Pb, 0.5 Bi. #2(Pb-Bi): 99.8 Pb, 0.2 Bi.	Measured in both the normal and superconducting (s) states.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-3; L-1; M-1,2; N-3.	K. Mendelssohn and J.L. Olsen (1950b); see also Mendelssohn and Olsen (1950c).
O.-1(Pb-Bi), 1(s)	Prepared from Johnson, Matthey No. 1932 Pb and No. 4213 Bi; 70 Pb, 30 Bi.	Fairly small grain size of 0.02 mm. Measured in both the normal (in magnetic fields up to 0.25 T) and superconducting (s) states. Graph of lattice conductivity in the superconducting state as a function of reduced temperature. Graph of thermal conductivity as a function of longitudinal magnetic fields.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-3; L-1; M-1; N-2, 3; P-2,4,5; Q-1,3.	J.L. Olsen (1952).
R.-1(s)(Pb-Bi), 1(s)(Pb-Bi) (strained), 1(s)(Pb-Bi) (ann)	Prepared from Johnson, Matthey 99.99 Pb; 99 Pb, 1 Bi.	Single crystal; prepared by melting; solidified slowly from one end; annealed 3 days at 270°C. Measured in the superconducting (s) state. #1(strained): strained by the equivalent of 1.6%. #1(ann): annealed at room temperature for a long period.	A-1; B-1; C-1; D-3(2); E-5, 6; F-4; G-2; N-3; P-2, 3, 4,5,9; Q-1.	R. M. Rowell (1960).

LEAD ALLOYS (cont'd)

(See FIGURES 48b and 49)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
L-1(Pb-Bi), 1 (s), 2(Pb-In), 2(s), 3(Pb-In), 3(s).	#1(Pb-Bi): 6 Bi. #2(Pb-In): 3 In. #3(Pb-In): 6 In.	Measured in both the normal and superconducting (s) states.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-3; L-1; M-1, 2; N-3; P-1, 2; Q-1, 3.	P. Lindenfeld (1961).
. . . . .	> 99.73 Pb.	Corroding Lead; equivalent to ASTM B29-55; k = 0.35 at 273 K.	. . . . .	Metals Handbook (1961).
. . . . .	99 Pb, 1 Sb.	1% Antimonial Lead; k = 0.33 at 273 K.	. . . . .	Same as above.
. . . . .	96 Pb, 4 Sb.	Hard Lead; k = 0.30 at 293 K.	. . . . .	Same as above.
. . . . .	94 Pb, 6 Sb.	Hard Lead; k = 0.29 at 293 K.	. . . . .	Same as above.
. . . . .	92 Pb, 8 Sb.	8% Antimonial Lead; k = 0.27 at 293 K.	. . . . .	Same as above.
. . . . .	91 Pb, 9 Sb.	9% Antimonial Lead; k = 0.27 at 293 K.	. . . . .	Same as above.
. . . . .	75 Pb, 15 Sb, 10 Sn.	Lead-Base Babbitt (SAE 14); equivalent to ASTM B23-49 alloy 7 and SAE 14; k = 0.24 at 293 K.	. . . . .	Same as above.
. . . . .	80 Pb, 15 Sb, 5 Sn.	Lead-Base Babbitt (Alloy 8); equivalent to ASTM B23-49 alloy 8; k = 0.24 at 293 K.	. . . . .	Same as above.


ANTIMONY
and BISMUTH ALLOYS
FIGURE 50
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
1
.8
.6
.5
.4
.3
.2
.1
.08
.06
.05
.04
.03
.02
.01
4
5
6
8
10
20
40
60
80
100
200
300
L. - Lip.
E.G. - Sb - 33 % Cd
G.N. - Bi - 50 % Sb
G.N. - Sb - 30 % Bi
Y. - 1 (b) - Bi Sb
G.N. - Bi - 9 % Sb
E.G. - Sb - 50 % Cd
Y. - 2 (b) - Bi Sb
Y. - 1 (a) - Bi Sb
E.G. - Sb - 48 % Cd
B. de H. - Rose
G.N. - Bi - 11 % Sb
Y. - 2 (a) - Bi Sb
G.N. - Bi - 13 % Sb

ANTIMONY ALLOYS
(See FIGURE 50)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
E.G.-Sb-50% Cd, Sb-48% Cd, Sb-33% Cd	Kahlbaum. Sb-50% Cd: 50 Sb, 50 Cd. Sb-48% Cd: 51.7 Sb, 48.3 Cd. Sb-33% Cd: 66.7 Sb, 33.3 Cd.	Cast; cooled slowly. Sb-33% Cd: "very hard".	A-1; B-1; C-1; D-1(2); F-4; G-3; L-1; M-2; S-1,2,5.	A. Eucken and G. Gehlhoff (1912).
G.N.-Sb-30% Bi, Bi-50% Sb	Sb-30% Bi: 70 Sb, 30 Bi. Bi-50% Sb: 50 Sb, 50 Bi.	Bi-50% Sb: see BISMUTH ALLOYS Table.	A-1; B-2; C-1; D-1(4); E-1; F-4; G-3; L-1; M-1,2; S-1,2,5.	G. Gehlhoff and F. Neumeier (1913a).

BISMUTH ALLOYS
(See FIGURE 50)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
L. - Lip.	Kahlbaum: 50 Bi, 25 Pb, 14 Sn, 11 Cd.	"Lipowitz alloy"; cast; specific density of 9.66 at 20°C. Melting point of 65°C.	A-1; B-1; C-1; D-2(2); E-2; F-4; G-3; L-1; S-1, 5.	C. H. Lees (1908).
G. N. - Bi-9% Sb, Bi-11% Sb, Bi-13% Sb, Bi-50% Sb.	Bi-9% Sb: 91 Bi, 9 Sb. Bi-11% Sb: 89 Bi, 11 Sb. Bi-13% Sb: 87 Bi, 13 Sb. Bi-50% Sb: 50 Bi, 50 Sb.	Specimen of 80 Bi - 20 Sb had values only 1.2% greater than G. N. - Bi-13% Sb.	A-1; B-2; C-1; D-1(4); E-1; F-4; G-3; L-1; M-1, 2; S-1, 2, 5.	G. Gehlhoff and F. Neumeier (1913a).
B. de H. -Rose	50 Bi, 25 Pb, 25 Sn.	"Rose's metal"; nearly eutectic. T_c = 8.46 K.	A-1; B-1; C-1; D-4(2); E-5; F-4; G-3; N-2; S-5.	H. Bremmer and W. J. de Haas (1936b).
. . . . .	Bi Sb.	Graph of lattice thermal conductivity at 80 K of Bi Sb as a function of total Sb.	. . . . .	M. E. Ertl (1966).
Y. -1(a), 1(b), 2(a), 2(b)	#1: 97 (atomic) Bi, 3 Sb. #2: 90 Bi, 10 Sb.	Single crystals. Rod axis parallel (a) and perpendicular (b) to trigonal axis.	A-9; B-1; C-3; D-1(2); G-3; L-1; M-1, 2; N-4, 5; R-1; S-1, 2.	T. Yazaki (1968).
. . . . .	Bi Sb.	Measurements of parallel and perpendicular thermal conductivity tensor components at 100 K for nine Bi alloys with 5-30% Sb and doped with ~ 0.1% Te.	. . . . .	V. M. Grabov, G. A. Ivanov, and V. S. Ponaryadov (1970).

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CERIUM ALLOY

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	Graphs of thermal resistivity, W, and Lorenz ratio for an antiferromagnetic alloy, CeAl, between 7 and 12 K. A cusp in dW/dT occurs at 9.5 K, the Néel transition temperature.	. . . . .	A. Fote and T. Mihalisin (1971).

URANIUM ALLOY

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	#1: balance U, 5.29 (weight) Cr. #2: balance U, 10.1 Fe.	Prepared by induction melt in vacuum in graphite crucible, cast in mold; machined. #1: uranium-chromium eutectic; k = 0.306 at room temperature. #2: uranium-iron eutectic; k = 0.092 at room temperature; a few cracks.	A-3, 6; B-2; C-3; D-1(2); E-8; F-5; G-3.	J. M. McKee (1953).

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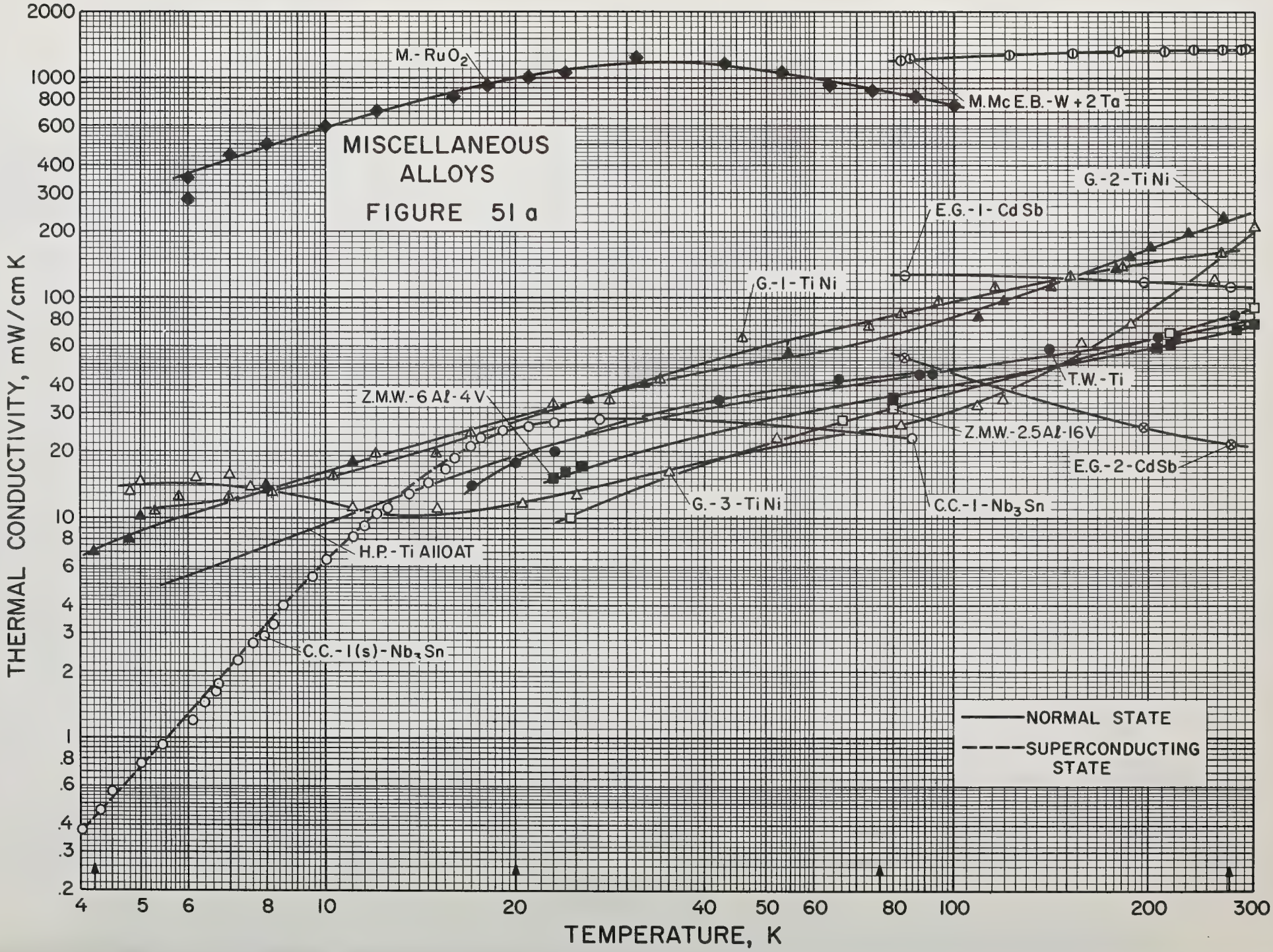
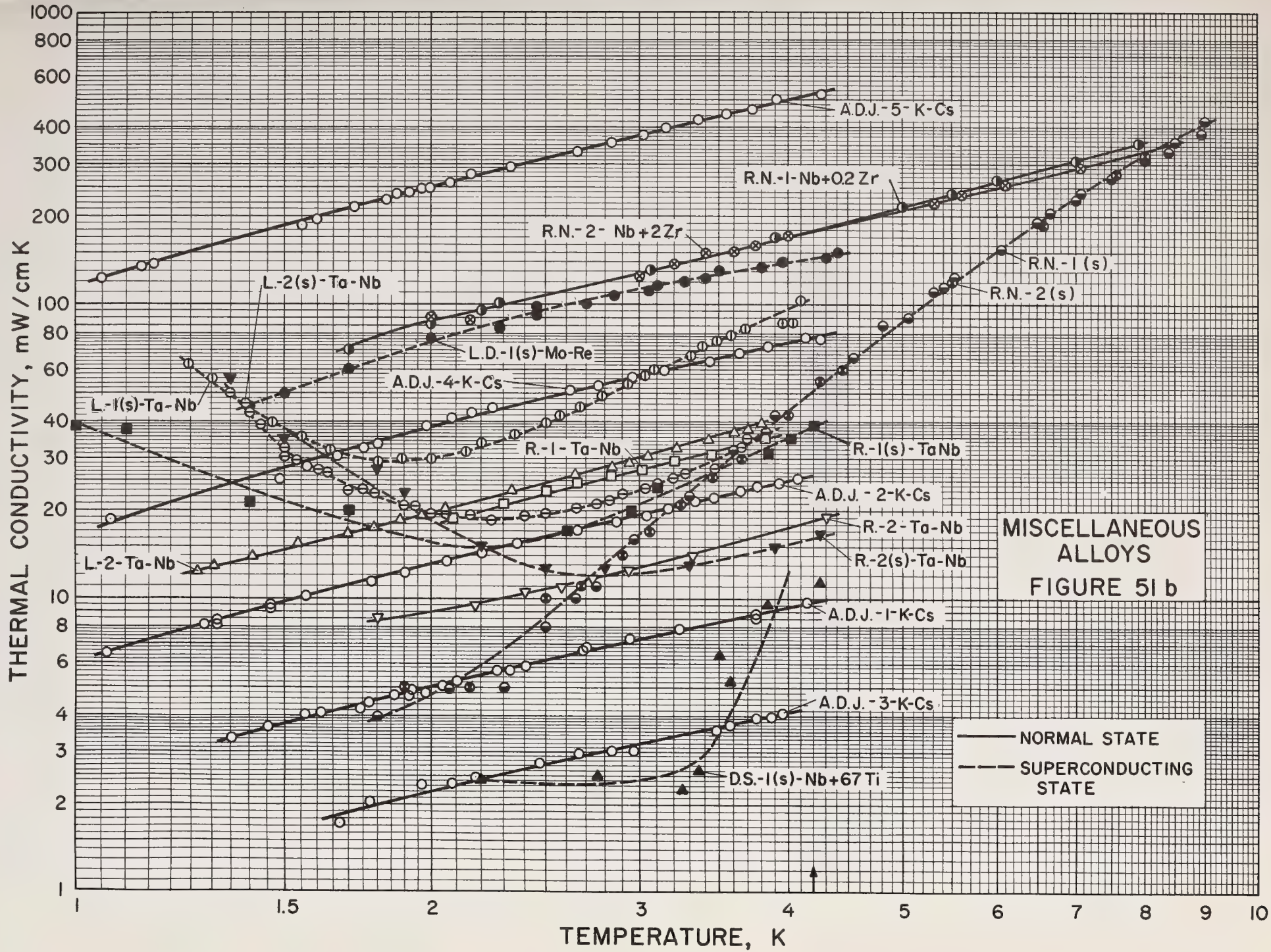

MISCELLANEOUS ALLOYS
FIGURE 51 a
THERMAL CONDUCTIVITY, mW/cm K
TEMPERATURE, K
M.- RuO_2
M.Mc E.B.-W + 2 Ta
G.-2-Ti Ni
E.G.-1-Cd Sb
G.-1-Ti Ni
T.W.-Ti
Z.M.W.-6 Al-4 V
Z.M.W.-2.5 Al-16 V
E.G.-2-CdSb
G.-3-Ti Ni
C.C.-1-Nb_3Sn
H.P.-Ti 8Mo 8V 2Fe 3Al
C.C.-1(s)-Nb_3Sn
NORMAL STATE
SUPERCONDUCTING STATE


THERMAL CONDUCTIVITY, mW/cm K
TEMPERATURE, K
1000
800
600
400
300
200
100
80
60
40
30
20
10
8
6
4
3
2
1
1
1.5
2
3
4
5
6
7
8
9
10
A.D.J.-5-K-Cs
R.N.-1-Nb+0.2 Zr
R.N.-2-Nb+2Zr
R.N.-1 (s)
R.N.-2 (s)
L.-2(s)-Ta-Nb
L.D.-1(s)-Mo-Re
A.D.J.-4-K-Cs
L.-1(s)-Ta-Nb
R.-1-Ta-Nb
R.-1(s)-TaNb
A.D.J.-2-K-Cs
R.-2-Ta-Nb
R.-2(s)-Ta-Nb
L.-2-Ta-Nb
A.D.J.-1-K-Cs
A.D.J.-3-K-Cs
D.S.-1(s)-Nb+67 Ti
MISCELLANEOUS ALLOYS
FIGURE 51 b
NORMAL STATE
SUPERCONDUCTING STATE

3.3. SEMICONDUCTORS AND SEMIMETALS

LITHIUM SEMICONDUCTOR

(See FIGURE 56a)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
H. P. W. -LiF	Korth.	After heavy neutron irradiation, specimen H. P. W. -1(b)-LiF on FIGURE 57b becomes an electronic semiconductor; total dosage was 1×10^{18} neutrons/cm^2.	A-1; B-1; C-1; D-1(2); F-4; G-2; O-3; P-2, 13; Q-1.	U. Himmler, H. Peisl, and W. Waidelich (1965).

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MAGNESIUM SEMICONDUCTORS

(See FIGURE 56a)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Mg_2 Sn. #1: 29.1(weight) Mg. #2: 29.2 Mg. #3: 29.3 Mg.	Intermetallic compound. #1: k = 0.358 at 80 K; k = 0.125 at 177 K; k = 0.0835 at 276 K. #2: k = 0.31 at 80 K; k = 0.13 at 177 K; k = 0.096 at 276. #3: k = 0.279 at 80 K; k = 0.125 at 177 K; k = 0.090 at 276 K.	A-1; B-1; C-1; D-1(2); F-2; G-2; M-1; O-3.	G. Busch and M. Schneider (1954a).
M.D. -Mg_2 Sn	Prepared from 99.999 Mg and Sn; uncompensated donor concentration of $1.8 \times 10^{16}/cm^3$; RRR(27) = 800.	Single crystal; grown by modified Bridgman technique; distilled under high vacuum; n-type. Four other specimens also measured, with similar results.	A-1; B-1; C-1; D-1(2), 3(2); G-2; M-1; O-3; P-2, 5, 8; Q-1, 4; R-1; S-1.	J. J. Martin and G. C. Danielson (1968).
M.S.D. -1, 2- Mg_2 Ge	#1: carrier concentration of $5 \times 10^{15}/cm^3$. #2: carrier concentration of $4 \times 10^{17}/cm^3$.	Single crystals; grown by modified Bridgman technique; distilled under high vacuum; n-type. #1: maximum of 12.0 W/cm-K at 13 K and 14.5 K.	A-1; B-1; C-1; D-1(2), 3(2); G-2; M-1; O-2, 3; P-2, 5, 8; Q-1.	J. J. Martin, H. R. Shanks, and G. C. Danielson (1969).

TITANIUM SEMICONDUCTORS

(See FIGURE 56b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
T.M.-1(a), 2-TiO_2	#1(a): carrier concentration of 10^{20} /cm^3. #2: National Lead Co.; doped with 0.1 (weight) Nb_2O_5, concentration of 1.6×10^{19} /cm^3 Nb-ion.	TiO_2 (rutile). #1(a): single crystal; cut from boule grown by Verneuil method; oxidized 2 days in air at 700°C; surfaces roughened with Si C paper with No. 600 for final finish; then H_2-reduced by heating in flowing H_2 gas for 2 hrs at 900°C; furnace cooled to near room temperature in 2-3 hrs; rod axis parallel to crystal a-axis. #2: Nb-doped TiO_2; cut from boule grown from rutile powder containing 0.1% (weight) Nb_2O_5.	A-1; B-1; C-1; D-1(2); E-3; F-4; G-3; O-3, 5, 6; P-2, 5, 8; S-2.	W.R. Thurber and A.J.H. Mante (1965).
. . . . .	TiO_2	See M.V.-2-TiO_2 on FIGURE 62c; see Titanium Ionic Crystal Table also; specimen #2 is also semiconducting.	. . . . .	A.J.H. Mante and J. Volger (1970).
. . . . .	TiO_2	See B.S.S.-2, 3-TiO_2 on FIGURE 62c; see Titanium Ionic Crystal Table also; specimens #2 and #3 also semiconducting.	. . . . .	V.N. Bogomolov, I.A. Smirnov, and E.V. Shadrichev (1970).

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MANGANESE SEMIMETALS

(See FIGURE 56b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
N. T. T. - $MnSi_{1.73}$	Starting materials: high-purity single-crystal Si, twice vacuum sublimed Mn.	Single crystal, higher manganese silicide; tetragonal structure; prepared by Bridgman technique; quartz ampoule lowered at rate of 1 cm/hr; cut by diamond disk; rod axis parallel to [001] axis.	L-1; M-1; O-1; P-15; S-1, 2.	E. N. Nikitin, V. I. Tarasov, and P. V. Tamarin (1969).

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COPPER SEMICONDUCTORS
(See FIGURE 56a)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
A. -Cu Sb S_2, Cu Sb Se_2	Prepared from electropolytechnical Cu, 99.999 Se, and pure S; stoichiometric ratio. Cu Sb S_2: carrier concentration of $10^{17}/cm^3$. Cu Sb Se_2: carrier concentration of $6 \times 10^{17}/cm^3$.	Single crystals; prepared by melting in vacuum of the stoichiometric ratio in quartz ampules; temperatures in oven raised 200°/hr to 1500 K, held there for 8-10 hrs; shaken by electromagnetic vibrator; remelted under vacuum at 1200 K. A specimen of Cu Sb Te_2 also measured; at room temperature, k = 0.014.	O-1; P-1; R-1; S-1, 2.	G. B. Adbullayev, R. Kh. Nani, Ya. N. Nasirov, and T. G. Osmanov (1964).
I. E. -Cu_2 Ge Se_3, Cu_2 Sn Se_3	Cu_2 Ge Se_3: carrier concentration of $4.6 \times 10^{20}/cm^3$. Cu_2 Sn Se_3: carrier concentration of $1.2 \times 10^{21}/cm^3$.	Specimens are p-type. Cu_2 Ge Se_3: prepared by Bridgman method. Cu_2 Sn Se_3: prepared by zone refining with 11 passes. Graphs of lattice thermal conductivity.	A-1; B-1; C-1; D-1(2); G-3; O-3; P-2, 3, 5, 8, 9, 12; S-1.	T. Irie and S. Endo (1969).

SILVER SEMICONDUCTORS

(See FIGURE 56a)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	#1: Ag Sb Te_2. #1(a): 25(mole) Sn Te. #1(b): 60 Sn Te. #1(c): 80 Sn Te. #1(d): 100 Sn Te.	#1: p-type; k = 0.0068 at 80 K; k = 0.0095 at 125 K; k = 0.0078 at 195 K; k = 0.0100 at 273 K; k = 0.0107 at 300 K. #1(a): k = 0.010 at 300 K. #1(b): k = 0.018 at 300 K. #1(c): k = 0.026 at 300 K. #1(d): k = 0.065 at 300 K. Table of electronic and lattice thermal conductivity.	G-3; P-2, 12; S-1, 2.	G. D. Cody, J. P. Dismukes, E. F. Hockings, and D. Richman (1959).
. . . . .	Ag_2 Te.	Graph of thermal conductivity as a function of electrical conductivity for undoped and doped Ag_2 Te.	. . . . .	P. F. Taylor and C. Wood (1961).
B. -Ag_2 Se	Ag_2 Se: carrier concentration of 5.7 x 10^{17} /cm^3.	Melted in quartz tube; cooled slowly; zone melted in graphite boat 0.5 mm/min; slowly cooled 5-10°/hr to 150°C, then 1-2°/hr through transition temperature; tempered several hours below transition temperature. Also measured 4 other specimens.	A-1; B-1; C-1; D-1(2); G-3; P-1; S-1, 2, 3.	Y. Baer, G. Busch, C. Fröhlich, and E. Steigmeier (1962); see also G. Busch, B. Hilti, and E. Steigmeier (1961).

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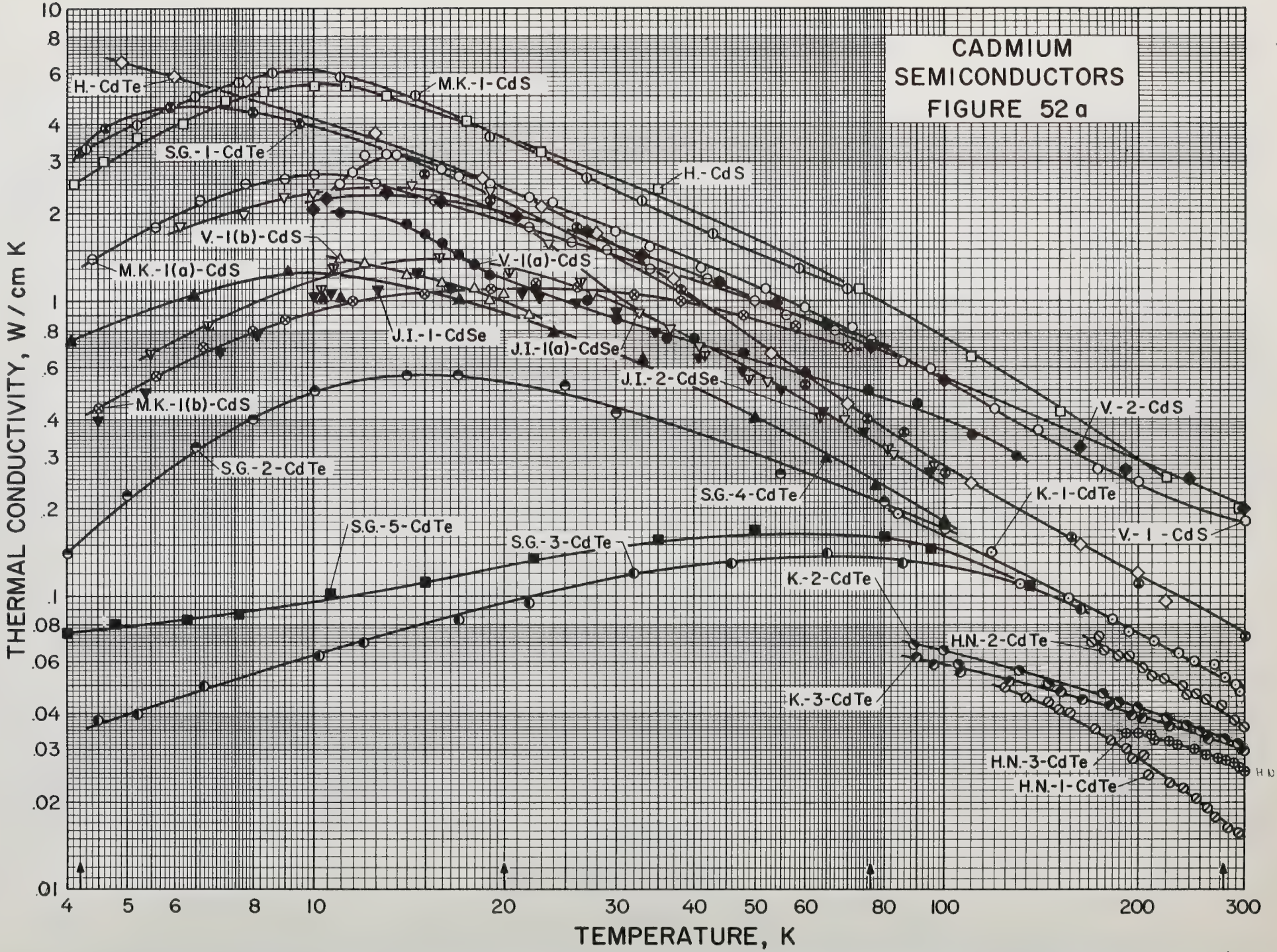
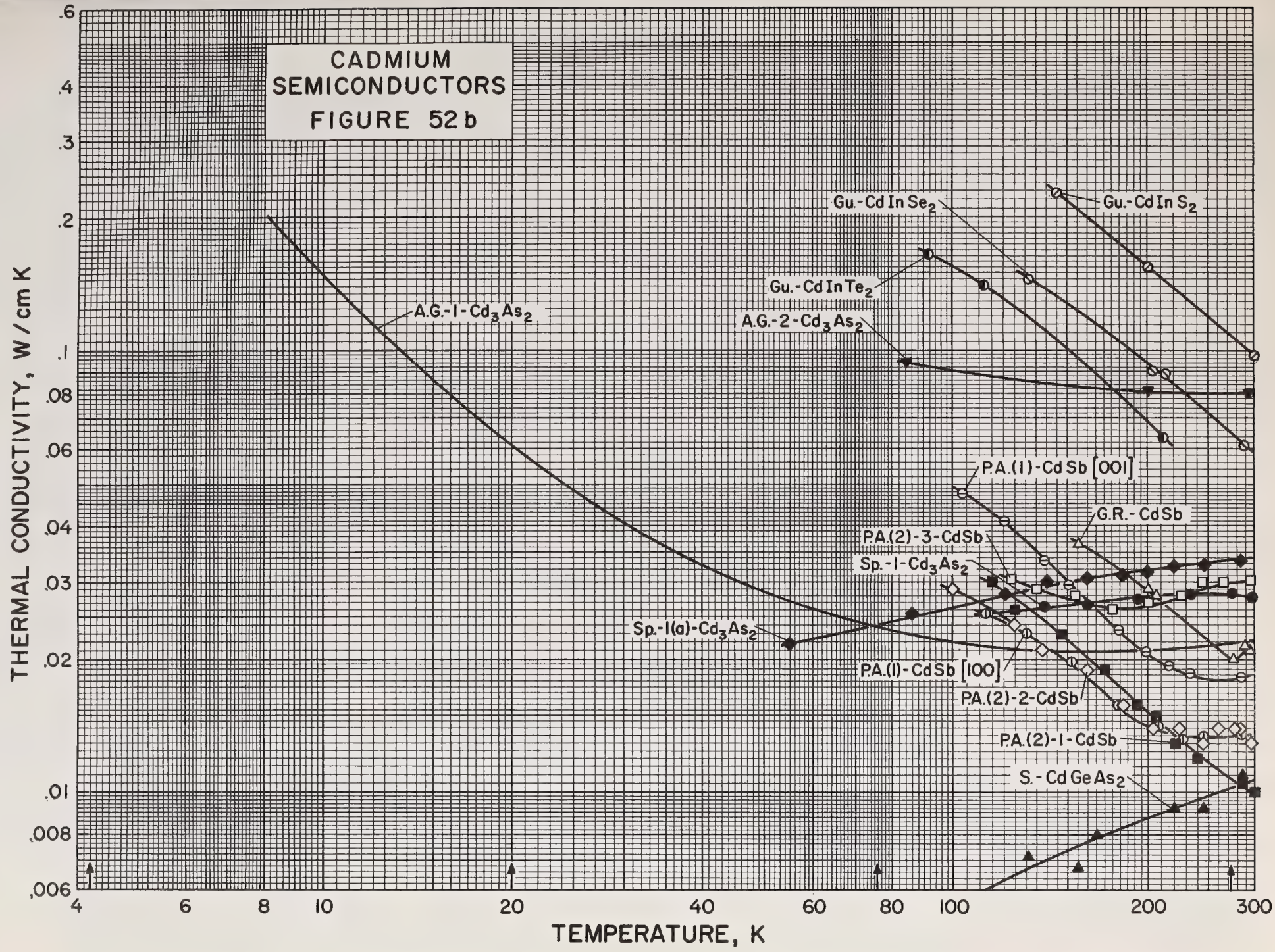
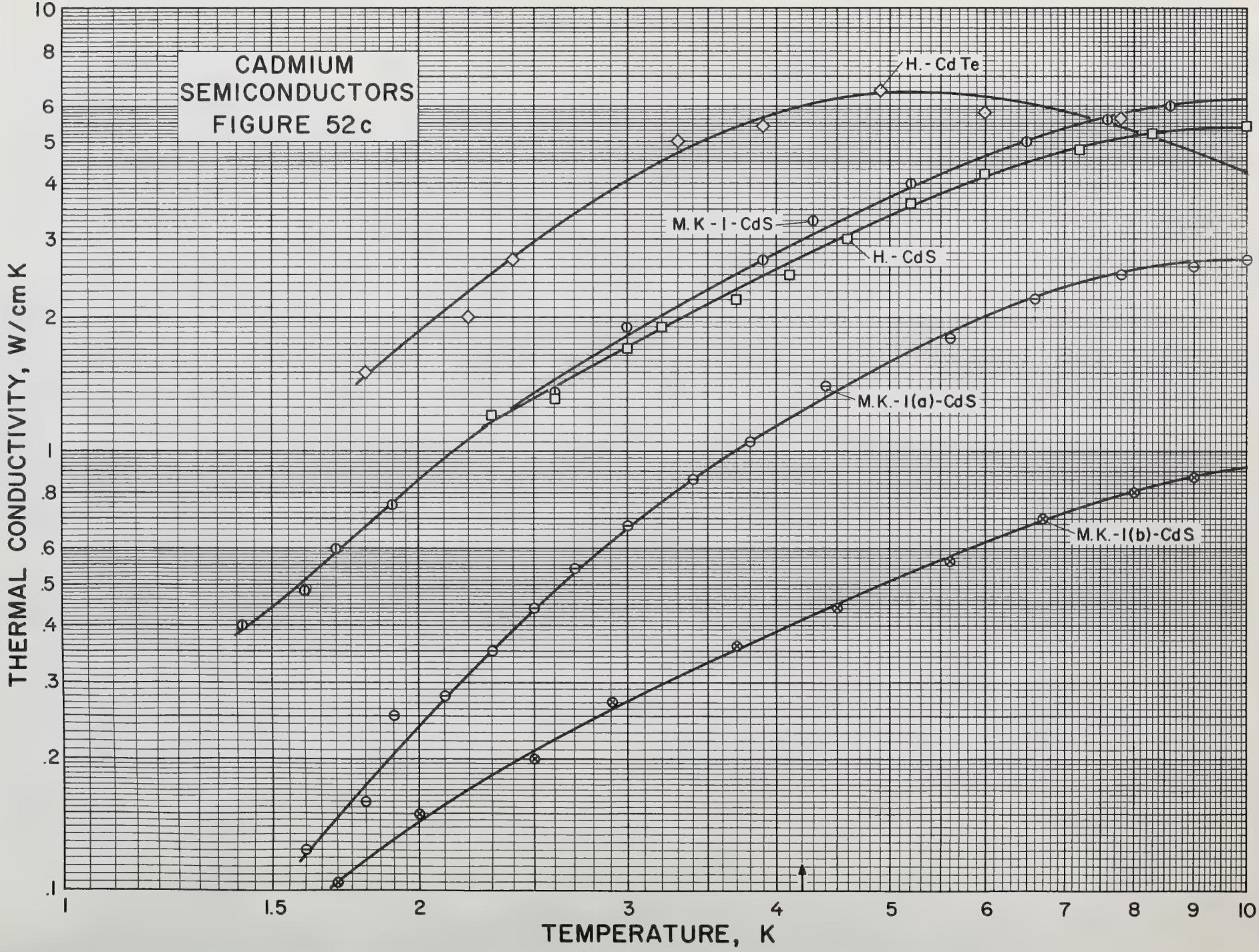
ZINC SEMICONDUCTORS
(See FIGURE 56a)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	#1: 90 Zn Te-10 Cd Se. #2: 50 Zn Te-50 Cd Se.	Crushed to fine powder; blended to correct composition, compressed under pressure of 2-5 metric ton/cm^2 at 300°C; repeatedly reannealed at higher temperature. Cubic crystal; solid solution; small inclusions. All results at 280 K. #1(a): annealed 10 hrs at 450°C and 8 hrs at 650°C, k = 0.059; #1(b): further annealed 20 hrs at 900°C, k = 0.047; #1(c): further annealed at 20 hrs at 900°C, k = 0.0443. Same conditions as #1-#2(a): k = 0.0157; #2(b): k = 0.0135; #2(c): k = 0.0128.	O-3, 5; P-1; Q-3.	A. V. Ioffe and A. F. Ioffe (1960).
F. J. S. -1, 1(a), 1(b), 1(c)-Zn Sb	Starting material for #1 and #1(b): 99.9999 pure. #1 and #1(a): Zn Sb. #1(b): 0.1 (atomic) Cu #1(c): 80 Zn Sb + 20 Cd Sb.	#1 and #1(b): zone melted; single crystal. #1(a) and #1(c): dropped from 480 to 400°C in 24 hrs.	A-1; B-1; C-1; D-1, 3(2); F-4; G-3; M-1; O-3; P-2, 4, 8, 12; R-1, 3; S-1, 2.	B. Fay, E. Justi, and G. Schneider (1965).
. . . . .	$Zn_3 As_2$; prepared with stoichiometric amounts of 99.9998 Zn and 99.9995 As.	Prepared in quartz ampule in vacuum at 50°C above melting temperature for 4 hrs; rocked; cooled at rate of 40°C/hr. k = 0.0127 at -35°C; k = 0.0124 at -16°C; k = 0.0121 at 5°C.	A-1; B-1; C-1; D-1(2); F-5; G-3; O-3, 5; P-2; Q-1, 4; S-1, 2.	D. P. Spitzer, G. A. Castellion, and G. Haacke (1966).
. . . . .	Zn Sb.	Graph of thermal conductivity of single crystals, p-type, of Zn Sb as a function of electrical conductivity, at 0°C, along the three principal axes.	. . . . .	P. J. Shaver and J. Blair (1966).


CADMIUM
SEMICONDUCTORS
FIGURE 52 a
THERMAL CONDUCTIVITY, W / cm K
TEMPERATURE, K
H.-CdTe
M.K.-1-CdS
S.G.-1-CdTe
H.-CdS
V.-1(b)-CdS
M.K.-1(a)-CdS
V.-1(a)-CdS
J.I.-1-CdSe
J.I.-1(a)-CdSe
J.I.-2-CdSe
M.K.-1(b)-CdS
V.-2-CdS
S.G.-2-CdTe
S.G.-4-CdTe
K.-1-CdTe
S.G.-5-CdTe
S.G.-3-CdTe
V.-1-CdS
K.-2-CdTe
H.N.-2-CdTe
K.-3-CdTe
H.N.-3-CdTe
H.N.-1-CdTe


CADMIUM
SEMICONDUCTORS
FIGURE 52b
THERMAL CONDUCTIVITY, W/cm K
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
.01
.008
.006
4
6
8
10
20
40
60
80
100
200
300
TEMPERATURE, K
Gu.-CdInSe2
Gu.-CdInS2
Gu.-CdInTe2
A.G.-2-Cd3As2
A.G.-1-Cd3As2
P.A.(1)-CdSb [001]
G.R.-CdSb
P.A.(2)-3-CdSb
Sp.-1-Cd3As2
Sp.-1(a)-Cd3As2
P.A.(1)-CdSb [100]
P.A.(2)-2-CdSb
P.A.(2)-1-CdSb
S.-CdGeAs2


CADMIUM
SEMICONDUCTORS
FIGURE 52c
H. - CdTe
M.K - I - CdS
H. - CdS
M.K. - I(a) - CdS
M.K. - I(b) - CdS
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
10
8
6
5
4
3
2
1
.8
.6
.5
.4
.3
.2
.1
1
1.5
2
3
4
5
6
7
8
9
10

CADMIUM SEMICONDUCTORS
(See FIGURES 52a-52c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	#1: Cd Se. #1(a): 70 Cd Se-30 Zn Te. #2: Cd Se. #2(a): 70 Cd Se-30 Zn Te. #3: Cd Se. #3(a): 70 Cd Se-30 Zn Te.	Crushed to fine powder, blended to correct composition, compressed under pressure of 2-5 metric ton/cm^2 at 300°C; repeatedly reannealed at higher temperature. Cubic crystals; single phase; solid solution; small inclusions of Cd Te. #1: annealed 10 hrs at 450°C, then annealed 8 hrs at 650°C; k = 0.063 at 280 K. #1(a): k = 0.012 at 280 K. #2: annealed as #1, then annealed 20 hrs at 900°C; k = 0.05 and 280 K. #2(a): k = 0.012 at 280 K. #3: annealed as #1, then annealed 40 hrs at 900°C; k = 0.04 at 280 K. #3(a): k = 0.01 at 280 K. Values quoted as (a) are at minimum as a function of composition; more specimens of Cd Se_{1-x} - Zn Te_x with $0 < x < 1$ measured.	A-1; B-1; C-1; D-1(2); F-4; G-3; O-3, 5; P-1; Q-3.	A. V. Ioffe and A. F. Ioffe (1960).
G. R. -Cd Sb	Stoichiometric Cd Sb; carrier concentration of $2 \times 10^{15}/cm^3$.	Single crystal; zone recrystallized; p-type.	A-6; O-3; P-2; S-1, 2.	S. M. Gusev and G. V. Rakin (1964).
H. -Cd S, Cd Te	Cd S: $\geq 10^{16}/cm^3$ impurity concentration. Cd Te: carrier concentration $\sim 5 \times 10^{17}/cm^3$.	Cd S: rod axis parallel to c axis; surface was roughened with 280-grit Si C.	A-1; B-1; C-1; D-1(2); E-4; F-4; G-2; O-2, 3, 5; P-2, 5, 8.	M. G. Holland (1964).
P. A. (1)-Cd Sb [100], Cd Sb [001]	Prepared with high purity Cd and Sb; $\leq 3\text{-}5 \times 10^{15}/cm^3$ impurity concentration.	Single crystals; grown by zone recrystallization; orthorhombic; p-type. Measured along the [100] and the [001] directions. Two specimens measured along each direction; specimens also measured along [010] direction, each 2% greater or less than the [001] direction.	A-1; B-1; C-1; D-1(2); F-2; G-2; O-6; P-1; R-1, 3.	I. M. Pilat and L. I. Anatychuk (1964a) and (1964b).
P. A. (2)-1, 2, 3-Cd Sb	Prepared with grade Kd-O Cd and grade SU-000 Sb. #1: $2.08 \times 10^{16}/cm$ impurity concentration. #2: Cd Sb + 0.1 Ag; $6.30 \times 10^{18}/cm^3$ impurity concentration. #3: Cd Sb + 3% Ag.	Prepared by fusing Sb with Cd that had been subjected to quadruple fractional vacuum distillation followed by zone-melting purification; alloys had 18 passes of additional recrystallization, then doped with Ag; p-type. Two other specimens with 0.1 and 1% Ag also measured.	A-1; B-1; C-1; D-1(2); F-2; G-2; O-1; P-1, 2; S-1, 2.	I. M. Pilat and L. I. Anatychuk (1964c).

CADMIUM SEMICONDUCTORS (cont'd)

(See FIGURES 52a-52c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	#1: Cd Sb; carrier density of $2 \times 10^{15}/cm^3$. #2: Cd Sb + 1 Cu. #3: Cd Sb + 1 Sn. #4: Cd Sb + 1 Ge. #5: Cd Sb + 2.67 Te.	#1: single crystal; p-type; k = 0.021 at 290 K. #2: p-type; k = 0.0183 at 290 K. #3: p-type; k = 0.025 at 290 K. #4: p-type; k = 0.019 at 290 K. #5: n-type; k = 0.0109 at 290 K.	A-6; O-3; P-2; S-1, 2.	S. M. Gusev and G. V. Rakin (1964).
S. G. -1, 2, 3, 4, 5- Cd Te	Prepared from 99.999 Cd and Te. #1: Cd Te; pure; $< 1 \times 10^{18}/cm^3$ Li, $< 5 \times 10^{17}/cm^3$ Zn, $< 4 \times 10^{17}/cm^3$ Be, $3 \times 10^{17}/cm^3$ Si, $2 \times 10^{17}/cm^3$ Fe, $< 1 \times 10^{17}/cm^3$ Mg, $< 9 \times 10^{16}/cm^3$ Ca, $< 6 \times 10^{16}/cm^3$ Mn. #2: Cd Te; $1.28 \times 10^{20}/cm^3$ Mn, $4 \times 10^{18}/cm^3$ Be, $< 3 \times 10^{18}/cm^3$ Zn, $2 \times 10^{18}/cm^3$ Li, $1 \times 10^{18}/cm^3$ Si, $< 1 \times 10^{18}/cm^3$ Mg, $< 9 \times 10^{17}/cm^3$ Ca, $< 6 \times 10^{17}/cm^3$ Fe. #3: Cd Te; $1.64 \times 10^{20}/cm^3$ Fe; $5 \times 10^{17}/cm^3$ C. #4: Cd Te; $1.4 \times 10^{20}/cm^3$ Zn. #5: Cd Te; $1.7 \times 10^{20}/cm^3$ Fe.	Preparation: grown from the melt at 0.5 cm/hr in fused quartz crucible coated with pyrolytic graphite; no zone purification; contained 1-10 twin boundaries/cm along (111) plane. Cubic zinc-blende structure. Six other specimens of Cd Te also measured.	A-1; B-1; C-1; D-1(2); E-1, 4; F-4; G-1; O-2, 3, 5; P-2, 4, 8, 10.	G. A. Slack and S. Galginaitis (1964).
H. N. -1, 2, 3- Cd Te	99.999 pure Cd and Te. #1: Cd Te. #2: Cd Te; 1 Te excess. #3: Cd Te; 1 Cd excess.	Melted in graphite-lined quartz tubes; held 48 hrs at 1150°C; drawn from melt at 1.2 cm/hr; annealed 6 hrs at 950°C. #2 and #3: single crystals. #1: stoichiometric. #1 and #2: p-type. Three other specimens of 0.1% excess also measured.	A-3; B-1; C-3; G-3; O-3, 5; R-1; S-1.	R. Horch and H. Nieke (1965).

CADMIUM SEMICONDUCTORS (cont'd)

(See FIGURES 52a-52c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Prepared from 99.9999 Cd and 99.9995 As. #1: $Cd_3 As_2$; $2.40 \times 10^{18}/cm^3$ carrier concentration. #2: $Cd_3 As_2$; doped with 0.1(weight) Cu; $1.56 \times 10^{18}/cm^3$ carrier concentration. #3: $Cd_3 As_2$; doped with 1.0 Se; $1.39 \times 10^{19}/cm^3$ carrier concentration.	Melted in carbon-coated quartz ampul; annealed 2-3 days just below melting point. Tetragonal D5 structure. Stoichiometric. #1; k = 0.044 at 247 K; k = 0.045 at 262 K; k = 0.0445 at 280 K. #2: k = 0.028 at 247 K; k = 0.027 at 262 K; k = 0.027 at 280 K. #3: k = 0.044 at 250 K; k = 0.045 at 262 K; k = 0.0445 at 276 K. A total of 30 other specimens also measured at room temperature, undoped and doped with Cu, Ag, Au, Ga, Se, and Ge. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-1(2); F-5; G-3; O-3, 5; P-2; Q-1; S-1, 2.	D. P. Spitzer, G. A. Castellion, and G. Haacke (1966).
K. -1, 2, 3-Cd Te	Prepared from cadmium pro analysi. #1: pure Cd Te; Ag, As, and Cu impurities. #2: Cd $Te_{0.9} S_{0.1}$; Ag, As, and Cu impurities. #3: Cd $Te_{0.9} Se_{0.1}$; Ag, As, and Cu impurities.	Single crystals; grown by Bridgmann technique; sphalerite structure. Three other specimens of Cd $Te_{1-x} S_x$ also measured.	A-3; B-1; C-3; D-1(2); F-5; G-3; O-3; P-2; R-3; S-1.	F. Kelemen, A. Néda, D. Niculescu, and E. Cruceanu (1967).
Sp. -1, 1(a)- $Cd_3 As_2$	#1: $Cd_3 As_2$; undoped; 2×10^{18} electrons/cm^3. #1(a): $Cd_3 As_2$; doped with 1.0(weight) Se; 1.5×10^{19} electrons/cm^3.	Prepared by fusion of the elements in vacuum; cut. A specimen of $Cd_3 As_2$ doped with 0.1% Cu also measured. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-1(2); F-5; G-3; N-9; O-3, 5; P-2; Q-1; S-1, 2, 5.	D. P. Spitzer (1968).
V. -1, 1(a), 1(b), 2-Cd S	Prepared from high-purity single-crystal material from Clevite Corp; sulfur compensated.	Hexagonal structure. #1: rod axis parallel to c axis. #1(a): specimen #1 then irradiated at total flux of 7.8×10^{17} 2-Mev e/cm^2; annealed 15 min at 148 K. #1(b): then irradiated at same flux again as #1(a); annealed 15 min at 250 K. #2: rod axis perpendicular to c axis. Specimen #1 also irradiated and annealed at 25, 225 and 300 K; results after 300 K anneal and irradiation were 2% greater than #1 at 11 K. Specimen #2 also irradiated and annealed identically to #1.	A-1; B-1; C-1; D-1(2); F-4; G-3; O-3, 6; P-2, 9, 11, 13	F. L. Vook (1968) and (1971).

CADMIUM SEMICONDUCTORS (cont'd)

(See FIGURES 52a-52c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
S.-Cd Ge As_2	. . . . .	Amorphous; prepared by fast-quenching substance from liquid state; etched.	A-1; B-1; C-1; D-1(2); F-4; G-3; O-3, 5; P-2; S-3.	L. Stourac (1969).
M.K.-1, 1(a), 1(b)-Cd S	Eagle Picher. #1: pure Cd S. #1(a): doped with Mn; 1 x 10^{-4} Mn S. #1(b): doped with Se; 0.0005 Cd Se.	Grown from melt by Bridgmann technique; etched 30 sec in HCℓ. n-type. Hexagonal structure. #1: rod axis parallel to c axis. #1(a) and #1(b): rod axis approximately parallel ± 15° to c axis. Specimen with rod axis perpendicular to c axis had results up to 10% less than #1. Cd S also doped with Co, Ni, and Zn, with results intermediate to #1(a) and #1(b).	A-1; B-1; C-1; D-1, 2(2); E-2, 4, 5; F-4; G-2; O-5, 6, 9; P-2, 3, 5, 8, 10; S-1.	G.E. Moore and M.V. Klein (1969).
A.G.-1, 2-Cd_3 As_2	Prepared at L.C.I.E. #1: 1.01 x 10^{18}/cm^3 carrier concentration; doped with 0.1 Au. #2: 1.74 x 10^{19} /cm^3 carrier concentration; doped with ~1 In.	Single phase; prepared by directional freezing. Other specimens of Cd_3 As_2 measured at 300 K: undoped, k = 0.0392; doped with 0.1% Ag, k = 0.0376; doped with 0.1% Au, k = 0.0335. Graph of lattice thermal conductivity.	B-1; D-1; G-3; L-1, 6; O-3; P-1; S-1, 5.	D. Armitage and H.J. Goldsmid (1969).
Gu.-Cd In S_2, Cd In Se_2, Cd In Te_2	. . . . .	Cd In S_2: synthesized by cooling on inclined ampoule; β-phase tetragonal with inclusions of α-phase trigonal; held at 1250°C for 40 hrs; cooled slowly; density of 4.42 g/cm^3. Cd In Se_2 and Cd In Te_2: held 4 hrs at 550-600°C, heated for 4-6 hrs at 750-850°C; cooled slowly; β-phase tetragonal; respective densities of 4.970 and 5.550 g/cm^3.	A-6; O-3; P-2; S-1, 2.	S.M. Gusev and G.V. Rakin (1964).
J.I.-1, 1(a), 2-Cd Se	Semi-elements Inc; >99.99 pure; undoped.	Single crystals; n-type; weakly hexagonal. #1: undoped; rod axis parallel to c axis; slight damage felt to cause surface defect that induced strains, may be responsible for lower values. #1(a): specimen then heat treated. #2: undoped; rod axis perpendicular to c axis. Specimen then heat treated; results identical to #2.	A-1; B-1; C-1; D-1, 3(2); F-4; G-3; O-3, 6; P-1, 5, 8; Q-1; S-1.	P.L. Jacobs and R.K. Irey (1970).

MERCURY SEMICONDUCTORS

(See FIGURE 56a)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
C. -Hg Te	Hg Te: acceptor concentration of 10^{18} - 10^{19} /cm^3.	Melted in quartz boat; heated at one end to 700°C, the other end at 350°C; cooled slowly to room temperature. p-type.	O-1; P-2.	R.O. Carlson (1958).
. . . .	Hg Se.	Graphs of lattice and electronic thermal conductivity of single and polycrystals of Hg Se. Graphs of thermal conductivity as a function of magnetic field up to 3.5 T between 90 and 100 K and 205 and 210 K.	. . . .	S. A. Aliev, L. L. Korenblit, and S. S. Shalyt (1966).
K. S. -Hg Te	Carrier concentration of 10^{19} /cm^3.	p-type; five other specimens with carrier concentrations between 3 x 10^{17} and 10^{20} /cm^3 also measured, the same results within experimental error.	A-1; B-1; C-1; C-1(2); F-4; G-3; M-1; O-1; P-2; R-1; S-2.	E. E. Kolosov and P. V. Sharavskii (1966).

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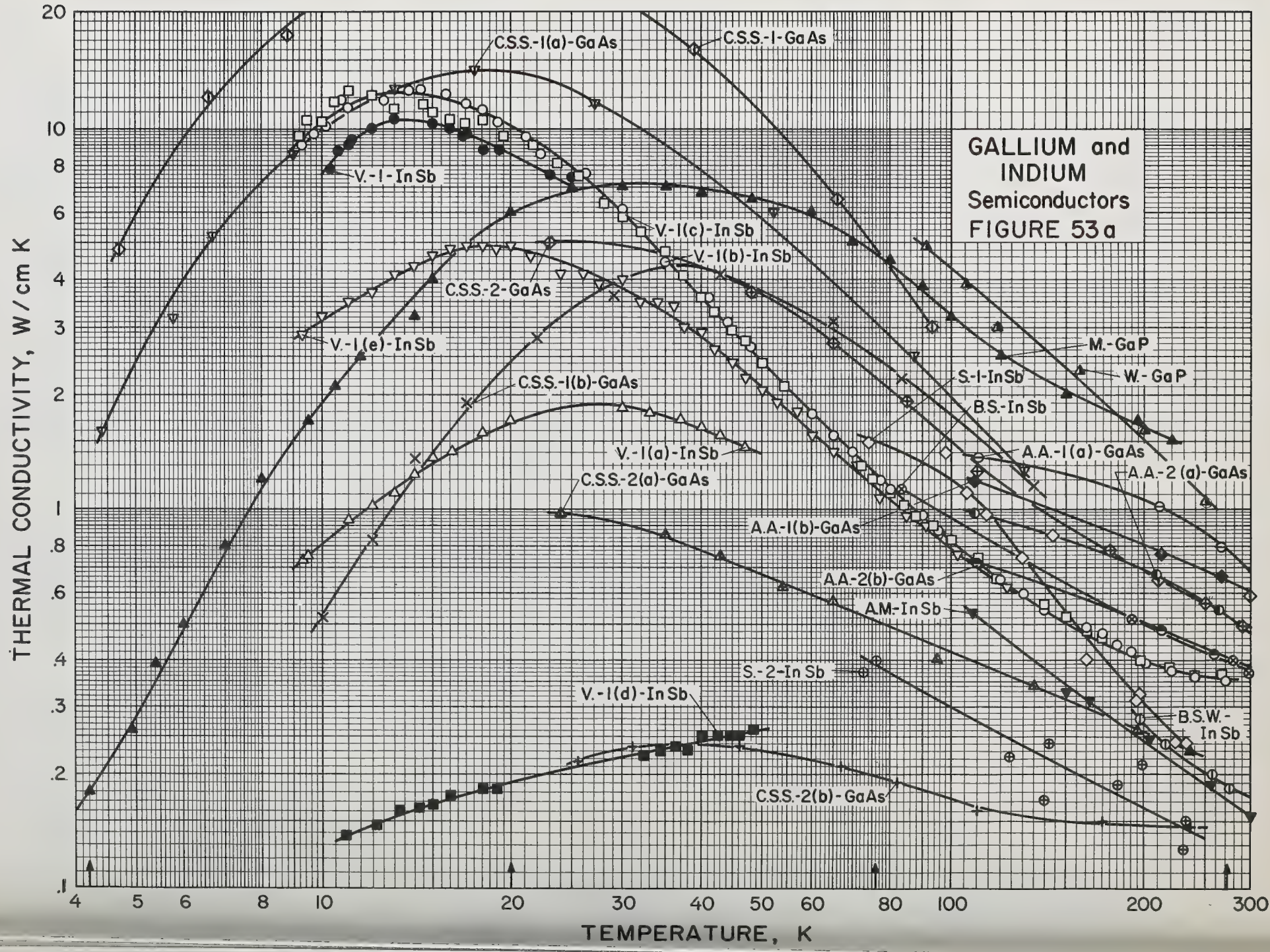
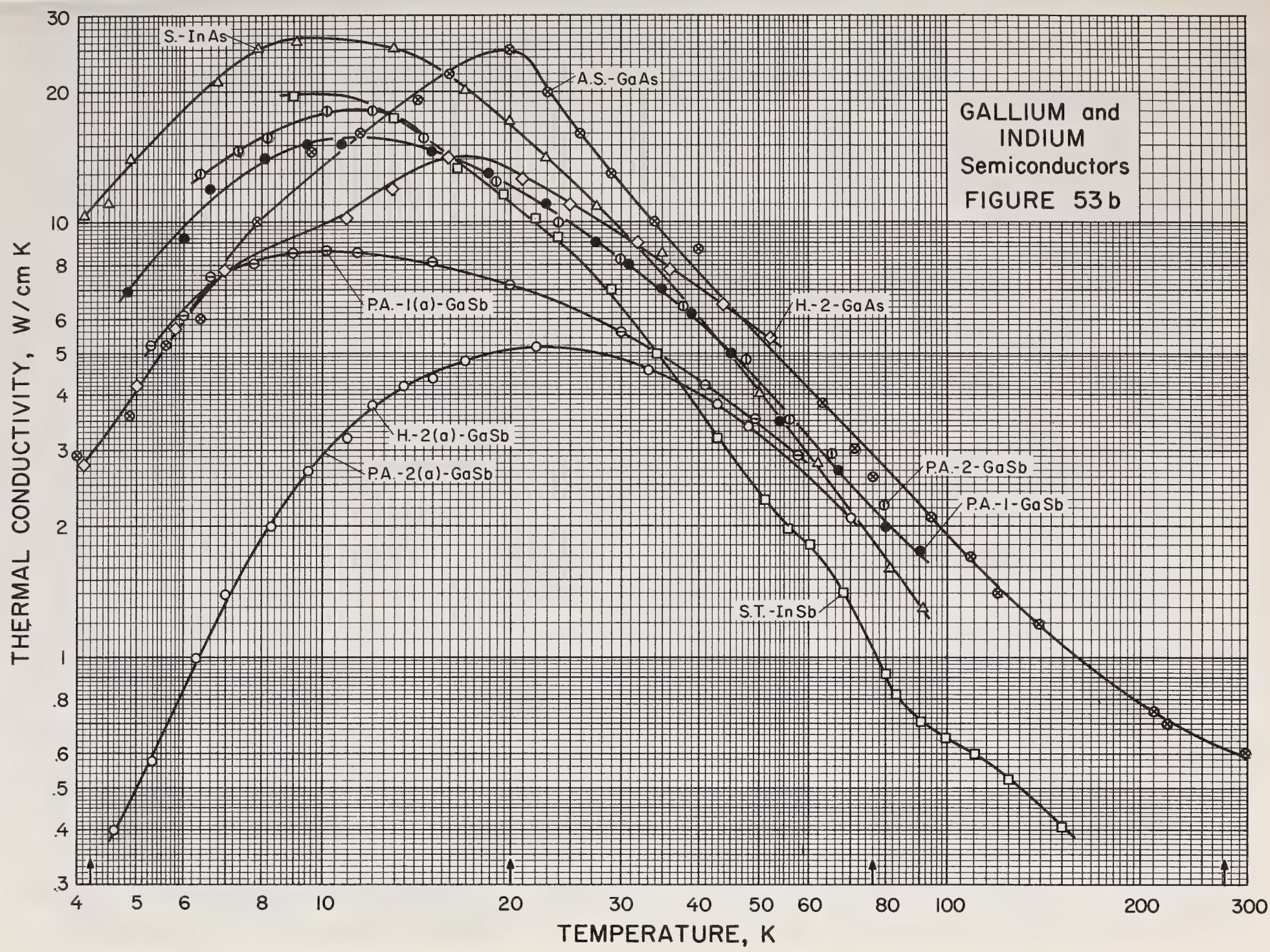

GALLIUM and INDIUM Semiconductors
FIGURE 53a
THERMAL CONDUCTIVITY, W / cm K
TEMPERATURE, K
20
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
4
5
6
8
10
20
30
40
50
60
80
100
200
300
C.S.S.-1(a)-GaAs
C.S.S.-1-GaAs
V.-1-InSb
V.-1(c)-InSb
V.-1(b)-InSb
C.S.S.-2-GaAs
V.-1(e)-InSb
M.-GaP
W.-GaP
S.-1-InSb
B.S.-InSb
C.S.S.-1(b)-GaAs
A.A.-1(a)-GaAs
A.A.-2(a)-GaAs
V.-1(a)-InSb
C.S.S.-2(a)-GaAs
A.A.-1(b)-GaAs
A.A.-2(b)-GaAs
A.M.-InSb
S.-2-InSb
V.-1(d)-InSb
B.S.W.-InSb
C.S.S.-2(b)-GaAs


GALLIUM and INDIUM Semiconductors
FIGURE 53b
S.-InAs
A.S.-GaAs
P.A.-1(a)-GaSb
H.-2-GaAs
H.-2(a)-GaSb
P.A.-2(a)-GaSb
P.A.-2-GaSb
P.A.-1-GaSb
S.T.-InSb
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
30
20
10
8
6
5
4
3
2
1
.8
.6
.5
.4
.3
4
5
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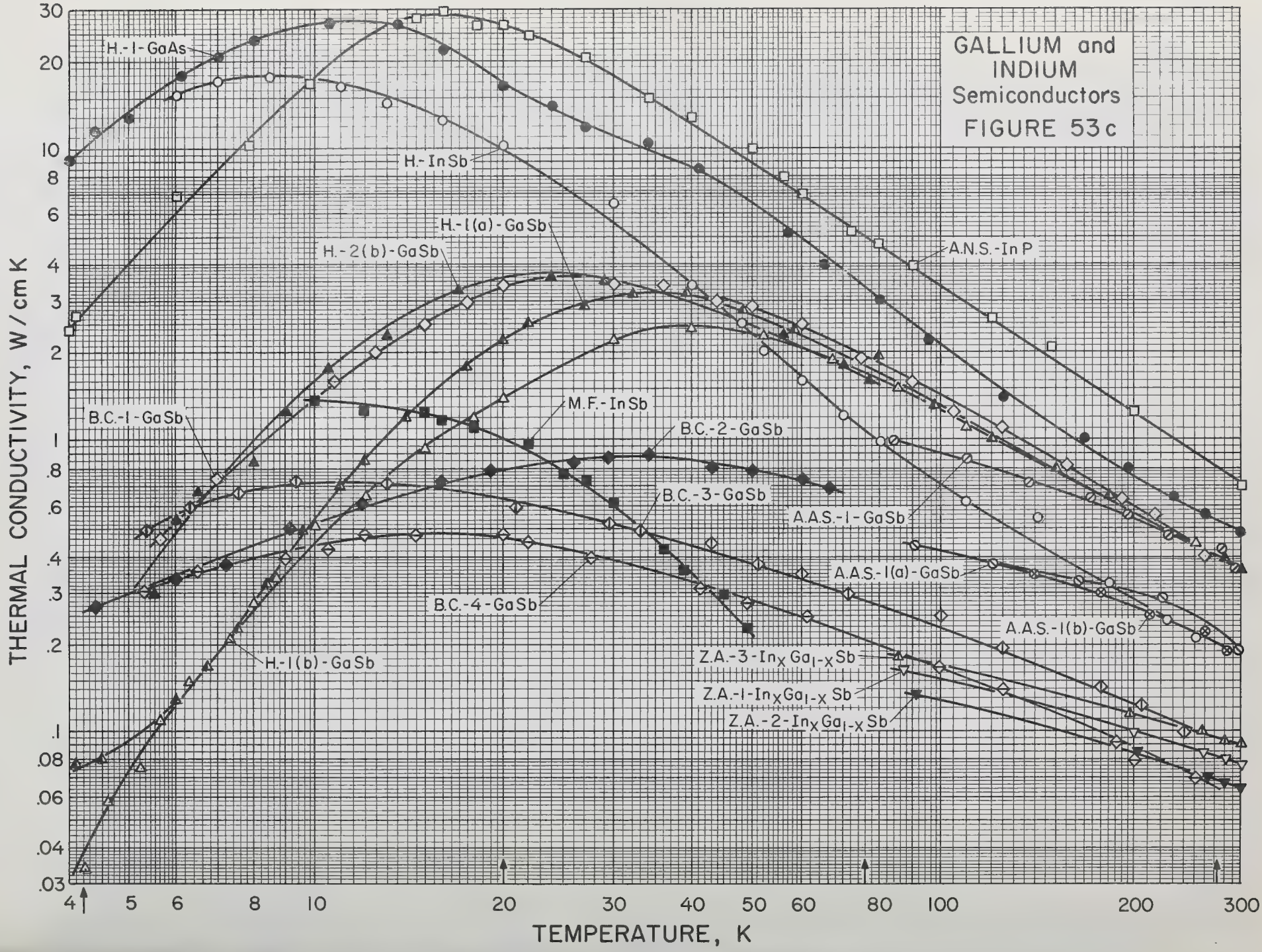
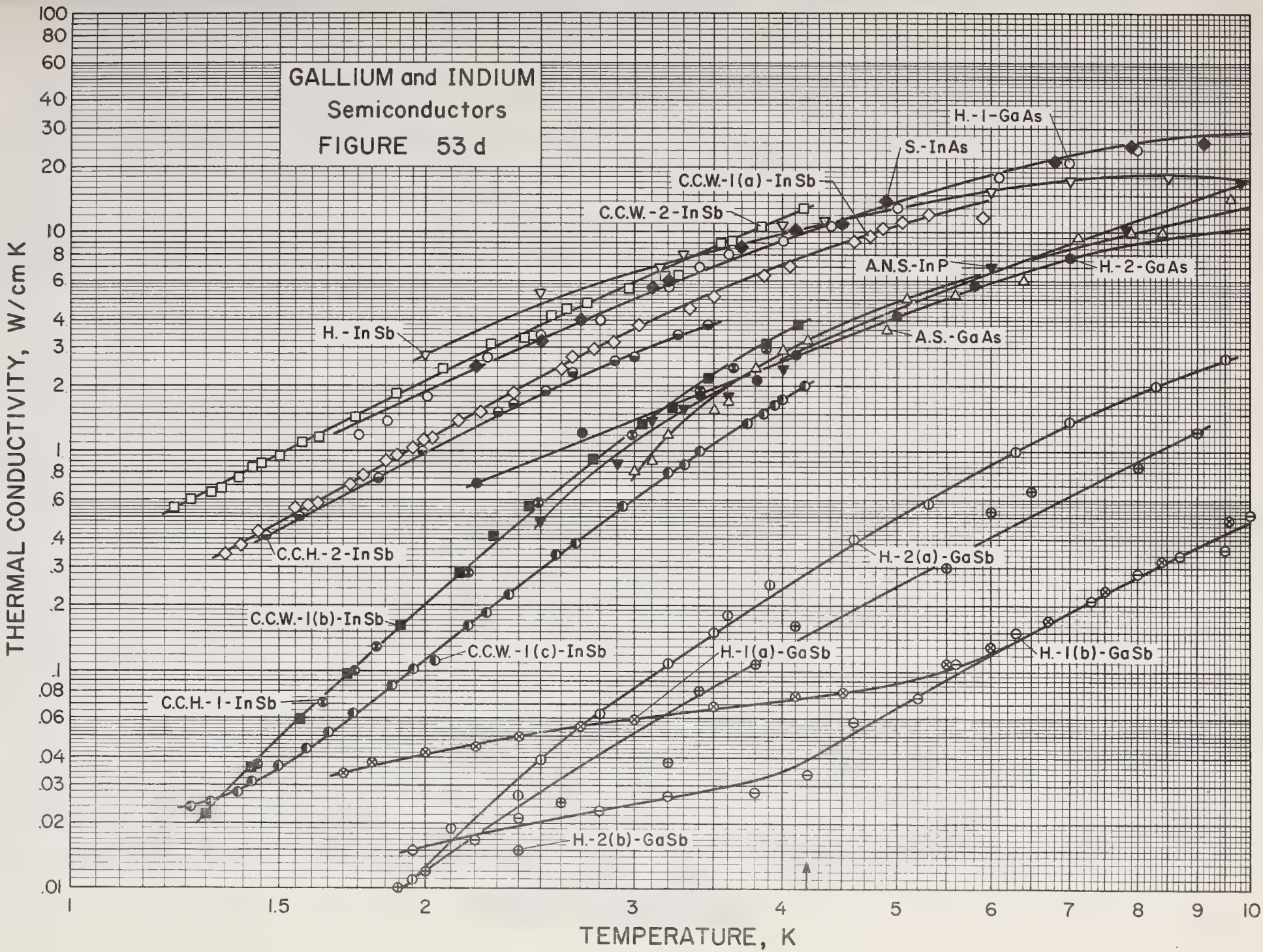
80
100
200
300


GALLIUM and INDIUM Semiconductors
FIGURE 53c
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
H.-1-GaAs
H.-InSb
H.-1(a)-GaSb
H.-2(b)-GaSb
A.N.S.-InP
B.C.-1-GaSb
M.F.-InSb
B.C.-2-GaSb
B.C.-3-GaSb
A.A.S.-1-GaSb
A.A.S.-1(a)-GaSb
B.C.-4-GaSb
A.A.S.-1(b)-GaSb
H.-1(b)-GaSb
Z.A.-3-InxGa1-xSb
Z.A.-1-InxGa1-xSb
Z.A.-2-InxGa1-xSb


GALLIUM and INDIUM
Semiconductors
FIGURE 53 d
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
H.-1-GaAs
S.-InAs
C.C.W.-1(a)-InSb
C.C.W.-2-InSb
A.N.S.-InP
H.-2-GaAs
A.S.-GaAs
H.-InSb
C.C.H.-2-InSb
H.-2(a)-GaSb
C.C.W.-1(b)-InSb
C.C.W.-1(c)-InSb
H.-1(a)-GaSb
H.-1(b)-GaSb
C.C.H.-1-InSb
H.-2(b)-GaSb
100
80
60
40
30
20
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
.01
1
1.5
2
3
4
5
6
7
8
9
10

GALLIUM SEMICONDUCTORS

(See FIGURES 53a-53d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	10-100 ppm detectable impurities: Ag, Al, Cu, Mg, Pb, and Si. #1: 99(mole) Ga As-1 In As. #2: 70 Ga As-30 In As.	Reacted elements in evacuated graphite crucible; held molten 1 hr; cooled slowly; zone leveled with 2 passes at rate of 15-25 cm/day. Inhomogenuities up to 4%. Coarse grains parallel to growth direction; no microcracks. #1: k = 0.37 at 300 K. #2: k = 0.06 at 300 K.	A-1; B-1; C-1; D-1(2); E-8; F-4; G-3; P-8, 9, 12; S-1, 2.	M.S. Abrahams, R. Braunstein, and F.D. Rosi (1959).
. . . . .	#1: Ga Sb. #2: Ga As. #3: 70 Ga P-30 Ga As. #4: Ga P.	At 20°C: #1, k = 0.44; #2, k = 0.51; #3, k = 0.13; #4, k = 1.05. Two other specimens of concentration intermediate to #3-#4 also measured, with intermediate results.	A-1; D-1(2); G-3; O-3, 5; P-2, 12; Q-1; S-2.	H. Weiss (1959).
. . . . .	Ga As.	Graph of lattice thermal conductivity as a function of composition of Ga As-In As at 300 K.	. . . . .	M.S. Abrahams, R. Braunstein, and F.D. Rosi (1959).
. . . . .	Ga As; 5(atomic) ppm C and O_2, ≤ 1 ppm Si, ≤ 0.1 ppm all other impurities; impurity concentration ≤ 6 x 10^{17} /cm^3. #2: ≤ 10^{16} /cm^3 Cu.	Single crystals; n-type. #1: prepared by horizontal Bridgman or floating-zone methods; density of 5.3161 g/cm^3; k = 0.45 at 25°C. #2(a): prepared by horizontal Bridgman method; annealed in 100-fold volume excess of molten KCN for 16 hrs at 700°C, quenched; density of 5.3164 g/cm^3; k = 0.42 at 25°C. #2(b): same as #2(a) except prepared by floating zone process; density of 5.3167 g/cm^3; k = 0.40 at 25°C.	A-1; B-2; C-1; D-1(2); F-4; G-3; P-2, 11.	J. Blanc, R.H. Bube, and L.R. Weisberg (1962).
A. A. -1(a), 1(b), 2(a), 2(b)- Ga As	#1(a): doped with Zn; carrier concentration of 10^{15} /cm^3. #1(b): doped with Zn; carrier concentration of 10^{19} - 10^{20} /cm^3. #2(a): doped with Se; carrier concentration of 10^{17} /cm^3. #2(b): doped with Se; carrier concentration of 4 x 10^{18}/cm^3.	#1(a)-#1(b): p-type. #2(a)-#2(b): n-type; degenerate. Three other specimens of n-type with intermediate concentrations also measured; results are between #2(a) and #2(b).	A-1; B-1; C-1; D-1, 3(2); G-3; P-9; S-1.	M.I. Aliev and G.T. Akmedli (1964).

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GALLIUM SEMICONDUCTORS (cont'd)

(See FIGURES 53a-53d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Ga Sb.	Graph of lattice and relative thermal conductivity as a function of composition of Ga Sb-In Sb at 300 K.	. . . . .	J. C. Wooley and A. G. Briggs (1964).
H. -1(a), 1(b), 2(a), 2(b)-Ga Sb	#1(a): 10^{17} /cm^3 carrier concentration. #1(b): 2.0 x 10^{17}/cm^3 carrier concentration. #2(a): 4.0 x 10^{18} /cm^3 carrier concentration. #2(b): 1.4 x 10^{18} /cm^3 carrier concentration.	Surfaces roughened with 280-grit Si C. #1(a)-#1(b): p-type. #2(a)-#2(b): n-type.	A-1; B-1; C-1; D-1(2); E-4; F-4; G-2; O-2, 3, 5; P-2, 5, 8, 9; Q-1.	M. G. Holland (1964).
H. -1, 2-Ga As	#1: 7 x 10^{15} /cm^3 carrier concentration. #2: $\sim 10^{18}$ /cm^3 carrier concentration.	Surfaces roughened with 280-grit Si C. Another specimen with carrier concentration the same as #1 with reduced cross-section also measured; results were nearly identical to #1 at high temperatures, and 20% less at low temperatures.	Same as above.	Same as above.
. . . . .	GaAs.	Unirradiated specimen gave results identical to H. -2-GaAs, within experimental error, from 10-300 K. Material bombarded with 2 MeV electrons at a temperature of 80 and 100 K; annealed; remeasured at five different temperatures between 325-575 K.	. . . . .	F. L. Vook (1964a).

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GALLIUM SEMICONDUCTORS (cont'd)

(See FIGURES 53a-53d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
C.S.S.-1, 1(a), 1(b), 2, 2(a), 2(b)-Ga As	#1 Monsanto Chemical Co.; impurity concentration of $\sim 10^{16}$ /cm^3. #1(a): Monsanto Chemical; doped with Se; dopant concentration of 1.3×10^{18} /cm^3. #1(b): Monsanto Chemical; doped with Zn; dopant concentration of 1.2×10^{19} /cm^3. #2: doped with Te; dopant concentration of 3×10^{18} /cm^3. #2(a): Ga $As_{0.9} P_{0.1}$; doped with Te; dopant concentration of 4×10^{18} /cm^3. #2(b): Ga $As_{0.5} P_{0.5}$; doped with Te; dopant concentration of 3×10^{18}/cm^3.	#1: Single crystal; n-type. Intermediate points at: 10.3 K, k = 34.8; 17.5 K, k = 43.5; 22.4 K, k = 42; 27.5 K, k = 30. #1(a): single crystal; n-type. #1(b): single crystal; p-type. Three other specimens of Ga As also measured, with intermediate results. #2, #2(a), and #2(b): prepared by closed-tube vapor transport method; grain size of several millimeters; specimens cut transverse to growth axis; all n-type. Four other specimens of intermediate composition of Ga $As_{1-x} P_x$ also measured, with intermediate results.	A-1; B-1; C-1; D-1(2); E-1, 4; F-4; G-3; O-3; P-2, 5, 8; Q-3.	R.O. Carlson, G. A. Slack, and S. J. Silverman (1965).
A.S.-Ga As	2 x 10^{16} /cm^3 electron concentration.	Single crystal; n-type.	A-1; B-1; C-1; D-1, 3(2); G-3; S-2.	S. A. Aliev and S. S. Shalyt (1966).
W.-Ga P	. . . . .	. . . . .	A-1; B-1; C-1; D-1(2); E-8; F-4; G-3; O-3, 9; P-2.	H. Wagini (1966).
A.A.S.-1, -(a), 1(b)-Ga Sb	#1: pure Ga Sb; 1.4×10^{17}/cm^3 carrier concentration. #1(a): doped with Zn; dopant concentration of 1.5×10^{20}/cm^3. #1(b): doped with Te; dopant concentration of 2.2×10^{18} /cm^3.	Single crystals; grown by direct synthesis from Ga and Sb; repeatedly zone-refined. #1 and #1(a): p-type. #1(b): n-type. Six other specimens also measured, with intermediate values.	A-1; B-1; C-1; D-1, 3(2); G-3; O-3, 9; P-2.	G. B. Abdullaev, M. I. Aliev and G. I. Safaraliev (1966).
. . . . .	. . . . .	Graphs of lattice and electronic thermal conductivity of Ga Sb.	. . . . .	S. A. Zeinalov and M. I. Aliev (1967).
M.-Ga P	Ga P.	Single crystal; p-type. Contained appreciable amounts of impurities.	A-1; B-1; C-1; D-1, 3(2); E-5; F-4; G-3; O-3; P-2; S-1, 2.	V. M. Muzhdaba, A. Ya. Nashel'skii, P. V. Tamarin, and S. S. Shalyt (1969).

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GALLIUM SEMICONDUCTORS (cont'd)

(See FIGURES 53a–53d)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
B. C. -1, 2, 3, 4-Ga Sb	#1: pure. #2: Ga Sb + 4.5 In Sb. #3: Ga Sb + 12.5 In Sb. #4: Ga Sb + 32.5 In Sb.	Also measured two other specimens with intermediate concentrations of Ga Sb-In Sb.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-3; O-3; P-2, 5, 12, 15; Q-1.	A. G. Briggs and L. J. Challis (1969).
P. A. -1, 1(a), 2, 2(a)-Ga Sb	Tellurium doped. #1: carrier concentration of $2.2 \times 10^{17}/cm^3$. #2: carrier concentration of $1.6 \times 10^{17}/cm^2$.	Grown by Czochralski method. #1, #1(a), and #2: n-type. #1(a): bombarded at 40°C with 40 MeV electrons to 4.2×10^{16} electrons/cm^2. #2(a): same as #1(a) to 28×10^{16} electrons/cm^2.	O-3; P-2, 5, 13.	A. -M. Poujade and H. J. Albany (1970).

INDIUM SEMICONDUCTORS

(See FIGURES 53a-53d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
B.S.-In Sb	. . . . .	Intrinsic. Two other specimens also measured with results within 10% of B.S.-In Sb. Graph of electronic thermal conductivity.	A-1; B-1; C-1; D-1(2); F-2; G-2; L-1; M-1; O-3.	G. Busch and M. Schneider (1954a) and (1954b).
. . . . .	In Sb; $\sim 3 \times 10^{17}/cm^3$ carrier concentration.	In Sb; single crystal; k = 0.23 at 232 K.	A-3; B-2; C-1; D-1(2); F-4; G-3.	Y. Kanai and R. Nii (1959).
. . . . .	#1: In Sb. #2: In As. #3: 62 In As - 38 In P. #4: In P.	At 20°C: #1, k = 0.155; #2, k = 0.354; #3, k = 0.108; #4, k = 0.760. Four other specimens of concentration intermediate to #2-#4 also measured, with intermediate results.	A-1; D-1(2); G-3; O-3, 5; P-2, 12; Q-1; S-2.	H. Weiss (1959).
M.F.-In Sb	Carrier concentration of $5.1 \times 10^{16}/cm^3$.	Single crystal; p-type.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-3; O-3; P-2, 5, 8.	E. V. Mielczarek and H. P. R. Frederikse (1959).
. . . . .	10-100 ppm detectable impurities: Ag, Aℓ, Cu, Mg, Pb, and Si. #1: In As. #2: 43(mole) In As-57 Ga As.	Reacted elements in evacuated graphite crucible; held molten 1 hr; cooled slowly; zone leveled with 2 passes at rate of 15-25 cm/day. Inhomogenuities up to 4%. Coarse grains parallel to growth direction; no microcracks. #1: k = 0.29 at 300 K. #2: k = 0.05 at 300 K. Three intermediate concentrations also measured, with intermediate results.	A-1; B-1; C-1; D-1(2); E-8; F-4; G-3; P-8, 9, 12; S-1, 2.	M. S. Abrahams, R. Braunstein, and F. D. Rosi (1959).
B.S.W.-In Sb	Carrier concentration of $1.2 \times 10^{16}/cm^3$.	Single crystal; n-type.	A-1; B-1; C-1; D-1(2); F-2; G-2; L-1; M-1; O-3; R-1; S-1, 2, 5.	G. Busch, E. Steigmeier, and E. Wettstein (1959); see also Busch and Steigmeier (1961).
. . . . .	$In_2 Te_3$.	See "TELLURIUM SEMICONDUCTORS".	. . . . .	V. A. Petrusevich, V. M. Sergeeva, and I. A. Smirnov (1960).

INDIUM SEMICONDUCTORS (cont'd)

(See FIGURES 53a-53d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
C.C.H.-1,2-In Sb	Royal Radar Establishment. #1: carrier concentration of $2 \times 10^{16}/cm^3$ at 77 K; Ge doped. #2: carrier concentration of $1.4 \times 10^{17}/cm^3$ at 77 K; Te doped.	Cut from single crystals grown from the melt; specimen axis perpendicular to direction of growth. Sandblasted with 44-79 mesh powder. #1: p-type. #2: n-type.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-2; O-5; P-2, 3, 5; Q-1, 4.	L. J. Challis, J. D. N. Cheeke, and J. B. Harness (1962).
S.-In As	Carrier concentration of $3 \times 10^{16}/cm^3$.	n-type. Also measured in a magnetic field of up to 1 T, with no appreciable effect on the thermal conductivity.	A-1; B-1; C-1; D-4(2); E-5; F-4; G-3; N-2; O-3; P-2, 3, 5, 8; S-1, 2.	S. S. Shalyt (1963).
. . . . .	In Sb.	Graph of relative thermal conductivity as a function of composition of In Sb-Ga Sb alloys at 300 K.	. . . . .	J. C. Wooley and A. G. Briggs (1964).
H.-In Sb	Carrier concentration of $7 \times 10^{13}/cm^3$.	Surfaces roughened with 280-grit silicon carbide powder and ends coated with indium.	A-1; B-1; C-1; D-1(2); E-4; F-4; G-2; O-2, 3, 5; P-2, 5, 8, 9; Q-1.	M. G. Holland (1964).
S. T.-In Sb	"Very pure"; carrier concentration of $7 \times 10^{13}/cm^3$.	Single crystal; n-type.	A-1; B-1; C-1; D-4(2); E-5; F-4; G-3; P-2, 5; Q-1; S-2.	S. S. Shalyt and P. V. Tamarin (1965).
. . . . .	In Sb; doped with In_2Te_3. #1: 0.5(mole) In_2Te_3; carrier concentration of $1.04 \times 10^{19}/cm^3$. #2: 5 In_2Te_3; carrier concentration of $0.88 \times 10^{19}/cm^3$.	#1(a): measured at 110 K at different lengths of anneal time at 450°C: 0 hr, k = 0.158; 12 hrs, k = 0.164; 50 hrs, k = 0.172, 100 hrs, k = 0.170. #1(b): measured at 300 K: 0 hr, k = 0.090; 12 hrs, k = 0.092; 50 hrs, k = 0.093; 100 hrs, k = 0.095. #2(a): at 110 K: 0 hrs, k = 0.061; 12 hrs, k = 0.078; 50 hrs, k = 0.10; 100 hrs, k = 0.105. #2(b): at 300 K: 0 hrs, k = 0.035; 12 hrs, k = 0.04; 50 hrs, k = 0.044; 100 hrs, k = 0.046.	A-1; B-1; C-1; D-4(2); E-5; F-4; G-3.	M. I. Aliev and A. Yu. Dzhangirov (1965).

INDIUM SEMICONDUCTORS (cont'd)

(See FIGURES 53a-53d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
C.C.W.-a(a), 1(b), 1(c), 2-In Sb	Royal Radar Establishment. #1(a): Ge doped; carrier concentration of $6.9 \times 10^{14}/cm^3$. #1(b): Ge doped; carrier concentration of $2.0 \times 10^{16}/cm^3$. #1(c): Ge doped; carrier concentration of $4.5 \times 10^{17}/cm^3$. #2: Te doped; carrier concentration of $5.7 \times 10^{16}/cm^3$.	Single crystals; uncompensated; surfaces sand-blasted with 44-79 mesh powder. #1(a)-#1(c): p-type. #2: n-type. Three other specimens of p-type with intermediate carrier concentrations also measured in transverse magnetic fields up to 0.8 T, with no detectable difference in thermal conductivity.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-2; P-2, 5, 12; Q-4.	L. J. Challis, J. D. N. Cheeke, and D. J. Williams (1965).
A.M.-In Sb	Carrier concentration of 7-9 x $10^{17}/cm^3$.	Graph of electronic and lattice thermal conductivity.	A-1; P-2; Q-1, 4; R-1.	Kh. I. Amirkhanov and Ya. B. Magomedov (1965).
A.N.S.-In P	Carrier concentration of $2 \times 10^{16}/cm^3$.	Coarse grained; contained a considerable number of impurities, probably compensated.	A-1; B-1; C-1; D-1, 3(2); E-5; F-4; G-3; P-2, 5, 8; Q-1; S-2.	S. A. Aliev, A. Ya. Nashel'skii and S. S. Shalyt (1965).
V.-1, 1(a), 1(b), 1(c), 1(d), 1(e)-In Sb	Prepared from Ohio Semiconductor high purity material. #1: carrier concentration of 3×10^5 $cm^2/V\text{-}sec$ at 80 K.	Single crystal; initially n-type. #1: specimen unirradiated and unannealed. After measurement of #1, specimen irradiated in ⟨111⟩ direction to a total flux of 2.08×10^{16} (2 MeV e)/cm^2; maximum temperature of specimen tips never exceeded 25 K; p-type. Isochronal anneals performed and specimen measured: #1(a), #1(b) 349 K. Intermediate anneal temperatures had intermediate results; #1(c) anneal at 400 K resulted in thermal conductivity identical to #1. Then specimen irradiated under same conditions to a total flux of 6.1×10^{17} (2-MeV e)/cm^2. Isochronal anneals performed and specimen measured: #1(d), 25 K; #1(e), 429 K. Intermediate anneal temperatures had intermediate results. Rod axis parallel to ⟨110⟩ direction.	A-1; B-1; C-1, 4; D-1(2); F-4; G-2; P-2, 8, 9.	F. L. Vook (1966); see also Vook (1964 b).

INDIUM SEMICONDUCTORS (cont'd)

(See FIGURES 53a-53d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
S.-1, 2-In Sb	#1: Exotic Materials; impurity concentration of 10^{16} /cm^3. #2: heavily doped, 50 Cd and 50 Zn; impurity concentration of 10^{20} /cm^3.	#1: single crystal; n-type; cubic lattice structure; rod axis parallel to (111) axis. #2: p-type.	A-6; B-2; C-1; D-1(6); E-2, 3; F-4; G-3; O-2, 3, 9; P-2, 5, 8.	E. J. Stephans (1966).
Z. A.-1, 2, 3- In_xGa_{1-x} Sb	#1: x = 0.90. #2: x = 0.50. #3: x = 0.25.	Another specimen with x = 0.75 also measured, with results intermediate to #1 and #2. Also measured specimen of In Sb. Graph of electronic thermal conductivity.	A-1; G-3; L-1; M-1; O-3, 5; P-2, 12; S-1.	S. A. Zeinalov and M. I. Aliev (1967).
. . . . .	Carrier concentration of 2-6 x 10^{19} /cm^3. #1: $In_{0.35}$ $Ga_{0.65}$ Sb. #2: $In_{0.86}$ $Ga_{0.14}$ Sb.	p-type. #1: k = 0.076 at 90 K; k = 0.062 at 200 K; k = 0.055 at 300 K. #2: k = 0.08 at 97 K; k = 0.074 at 225 K; k = 0.069 at 300 K. Two other specimens also measured, with intermediate results.	A-1; B-1; C-1; D-1(2); F-4; G-3; O-2, 3; P-2, 12; S-1, 2.	L. I. Kleshchinskii, M. E. Strzhalkovskii, and P. V. Sharavskii (1968).

ALUMINUM SEMICONDUCTORS

(See FIGURE 56a)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
W.-Aℓ Sb	. . . . .	. . . . .	A-1; B-1; C-1; D-1(2); E-8; F-4; G-3; O-3, 9; P-2.	H. Wagini (1966).
M.-1, 2-Aℓ Sb	. . . . .	Single crystals; contained appreciable amounts of impurities. #1: p-type. #2: n-type.	A-1; B-1; C-2; D-1, 3(2); E-5; F-4; G-3; O-3; P-2; S-1, 2.	V. M. Muzhdaba, A. Ya. Nashel'skii, P. V. Tamarin, and S. S. Shalyt (1969).

SILICON SEMICONDUCTORS
(See FIGURE 56b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
B. -1, 2-Si C	#1: doped with N_2, concentration of $10^{18}/cm^3$.	#1: single crystal; α-type, hexagonal structure; prepared by Lely method; N_2-doped. #2: β-type, cubic structure; prepared by pyrolysis of chlorosilicanes in an hydrogen atmosphere.	A-1; B-1; C-1; D-1, 3(2); G-3; P-3, 4, 5, 9; Q-1.	G. Bosch (1961).
S. -, 2, 3-Si C	#1: ~1 x $10^{17}/cm^3$ N_2. #2: Norton Co.; ~$10^{19}/cm^3$ Aℓ and N_2. #3: Norton Co.; 4 x $10^{19}/cm^3$ Aℓ.	Single crystals; grown from vapor phase: #1, in laboratory furnace; #2 and #3, in large electric-arc furnace. #1: n-type; possible impurities such as Fe-group elements; rod axis perpendicular to c axis. #2: n-type; rod axis perpendicular to c axis. #3: p-type; rod axis perpendicular to c axis.	A-1; B-1; C-1; D-1(2); E-1, 4; F-4; G-3; O-3; P-2, 5, 8; Q-1.	G. A. Slack (1964).

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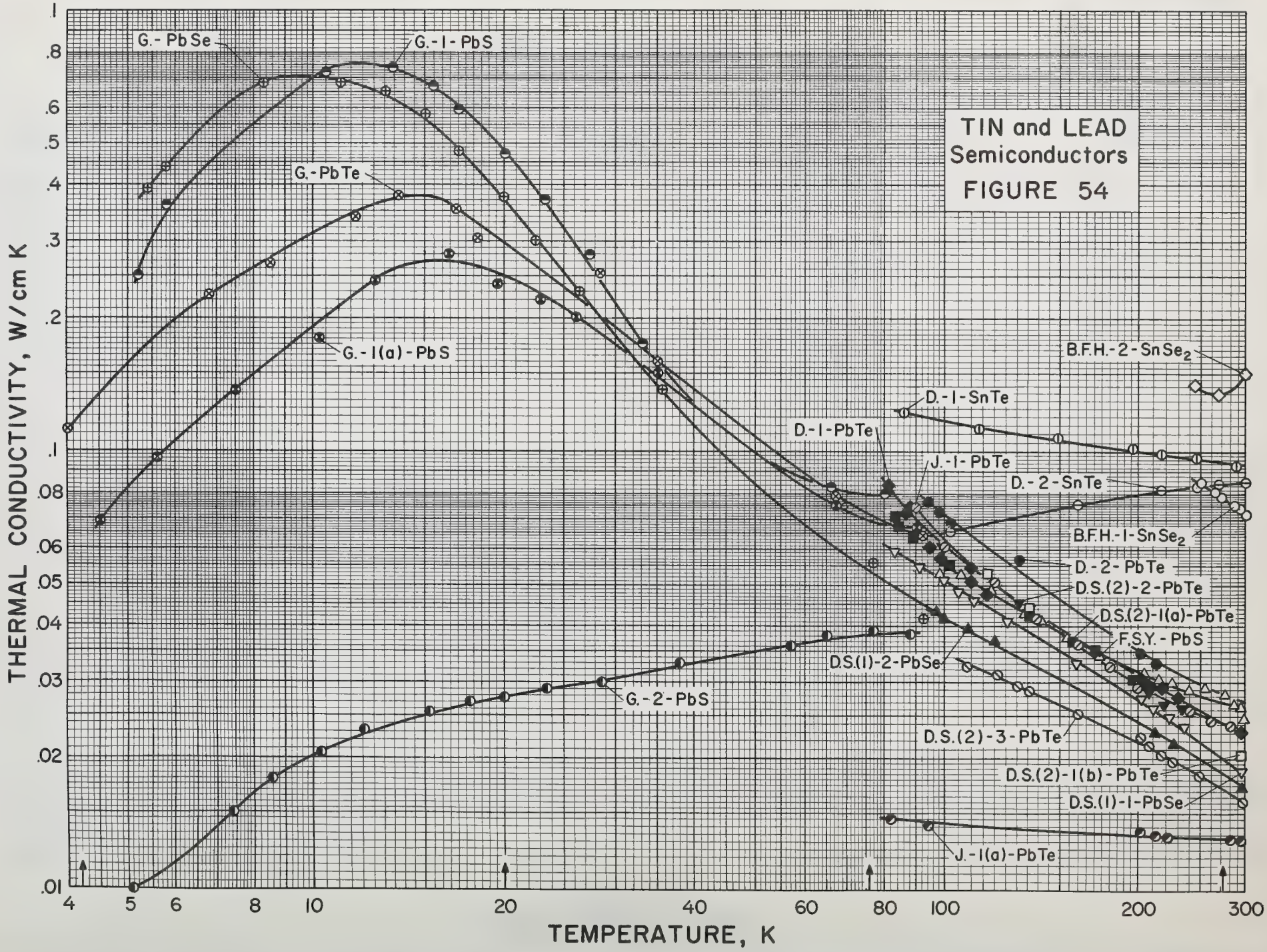
TIN and LEAD
Semiconductors
FIGURE 54
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
1
.8
.6
.5
.4
.3
.2
.1
.08
.06
.05
.04
.03
.02
.01
4
5
6
8
10
20
40
60
80
100
200
300
G.- PbSe
G.-1- PbS
G.-PbTe
G.-1(a)-PbS
G.-2-PbS
B.F.H.-2-SnSe2
D.-1-SnTe
D.-1-PbTe
J.-1-PbTe
D.-2-SnTe
B.F.H.-1-SnSe2
D.-2-PbTe
D.S.(2)-2-PbTe
D.S.(2)-1(a)-PbTe
F.S.Y.-PbS
D.S.(1)-2-PbSe
D.S.(2)-3-PbTe
D.S.(2)-1(b)-PbTe
D.S.(1)-1-PbSe
J.-1(a)-PbTe

TIN SEMICONDUCTORS

(See FIGURE 54)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	#1: Sn Te. #1(a): 90 Sn Te-10 Pb Te.	Crushed to fine powder, blended to correct composition, compressed under pressure of 2-5 metric ton/cm^2 at 300°C; repeatedly reannealed at higher temperature. Cubic crystal; solid solution; small inclusions. At 280 K - #1: k = 0.0318; #1(a): k = 0.0209.	A-1; B-1; C-1; D-1(2); F-4; G-3; O-3, 5; P-1; Q-3.	A. V. Ioffe and A. F. Ioffe (1960).
B. F. H. -1, 2-$Sn Se_2$	#1 and #2: carrier concentration of 6×10^{17} /cm^3.	Single crystals; prepared by sublimation and by Bridgman technique. #1: rod axis perpendicular to c-axis. #2: rod axis parallel to c-axis. Also measured two other single crystals and one polycrystal.	A-1; B-1; C-1; D-1; G-3; O-6; R-3; S-1, 2.	G. Busch, C. Fröhlich, and F. Hulliger (1961).
D. -1, 2-Sn Te	. . . . .	Brittle. Heat treated for up to 13 hrs. Two other specimens of Sn Te with intermediate carrier concentrations also measured, with intermediate results. Graph of electronic thermal conductivity.	A-1; B-1; C-1; D-1(4); F-2; G-2; M-1; N-5; O-3; P-2, 8, 9, 11; S-1, 5.	D. H. Damon (1966).

LEAD SEMICONDUCTORS
(See FIGURE 54)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
J.-1, 1(a)-Pb Te	#1: Pb Te; carrier concentration of $6.2 \times 10^{18}/cm^3$. #1(a): 70 Pb Te- 30 Pb Se.	Measured specimen similar to #1 with carrier concentration of $0.5 \times 10^{18}/cm^3$, with results 5-10% lower. Also measured specimens with intermediate compositions of 1, 5, and 15% Pb Se, with results intermediate to #1 and #1(a).	A-1; B-1; C-1; D-1(2); F-4; G-3; O-3; P-2, 12; R-1, 4.	A. F. Joffé (1956)
D.-1, 2-Pb Te	#1: carrier concentration of $6.0 \times 10^{17}/cm^3$. #2: carrier concentration of $9.8 \times 10^{18}/cm^3$.	#1: p-type; tempered in vacuum at about 500°C; annealed in vacuum 40 hrs at 300°C, quickly cooled. #2: n-type. Three other specimens also measured.	A-1; B-1; C-1; D-1(2); F-4; G-3; O-3, 5; R-1, 4; S-1.	E. D. Deviatkova (1957).
. . . . .	. . . . .	Calculated thermal conductivity of Pb Te between 140 and 300 K from diffusivity measurements.	. . . . .	R. Nii (1958); see also Y. Kanai and R. Nii (1959).
G.-1, 1(a), 2-Pb S	#1: carrier concentration of $1.7 \times 10^{18}/cm^3$. #1(a): 1(atomic) Pb replaced by Ag; carrier concentration of $1.8 \times 10^{19}/cm^3$. #2: Yukon; carrier concentration of $7.5 \times 10^{17}/cm^3$; 1-10 Fe, 0.1-1.0 Ag, Bi, Cu, and Sb, 0.01-0.1 Ca, Mg, Mn, Sn, and Zn, 0.001-0.001 Aℓ, Cd, and Si.	#1 and #1(a): p-type; synthetic; prepared by melting components together in sealed quartz tubes, then zone melting; few single crystals; average crystallite size of 5 mm x 1.5 mm and 10 mm x 3 mm, respectively. #2: n-type schistose crystalline state. Three other specimens similar to #2 also measured.	A-1; B-1; C-1; D-1(2); F-4; G-2; M-1; O-3; P-2, 3, 4, 8; Q-1; S-1, 2.	D. Greig (1960).
. . . . .	#1: Pb Se. #1(a): 50 Pb Se-50 Pb Te. #2: Pb Te. #3: 90 Pb Se-10 Pb S. #3(a): 90 Pb S - 10 Pb Se. #4: Pb S.	Crushed to fine powder, blended to correct composition, compressed under pressure of 2-5 metric ton/cm^2 at 300°C; repeatedly reannealed at higher temperature. Cubic crystal; solid solution; small inclusions. At 280 K- #1: k = 0.0159; #1(a): k = 0.00835; #2: k = 0.02. Specimens of intermediate composition also measured, with intermediate values. At 280 K - #3: k = 0.0134; #3(a): k = 0.0218; #4: k = 0.0293.	A-1; B-1; C-1; D-1(2); F-4; G-3; O-3, 5; P-1; Q-3.	A. V. Ioffe and A. F. Ioffe (1960).

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LEAD SEMICONDUCTORS (cont'd)

(See FIGURE 54)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
G. -Pb Se, Pb Te	Pb Se: carrier concentration of 5.4×10^{18} /cm^3. Pb Te: carrier concentration of 2.5×10^{18} /cm^3.	Pb Se and Pb Te: prepared same as G. -1-Pb S above; few single crystals; average crystallite size of 3 mm x 1 mm and 15 mm x 2 mm, respectively.	A-1; B-1; C-1; D-1(2); F-4; G-2; M-1; O-3; P-2, 3, 4, 8; Q-1; S-1, 2.	D. Greig (1960).
D. S. (1)-1, 2-Pb Se	#1: carrier concentration of 2.7×10^{18} /cm^3; doped with Se and Te. #2: carrier concentration of 6.4×10^{17}/cm^3; diffusion doped with Cu.	Single crystals; annealed several days between 300 and 700°C. #1: p-type; prepared by slow-growing in sealed evacuated quartz ampoule. #2: n-type; prepared same as #1. Three other specimens also measured. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-1(2); F-4; G-3; P-2; Q-4; S-2.	E. D. Devyatkova and I. A. Smirnov (1961).
D. S. (2)-1(a), 1(b), 2, 3-Pb Te	Prepared from 99.99 Pb, and Te twice sublimed in hydrogen. #1(a): stoichiometric; carrier concentration of 5.3×10^{17} /cm^3. #1(b): stoichiometric; carrier concentration of 4.0×10^{17}/cm^3. #2: carrier concentration of 4×10^{17}/cm^3; 1(weight) excess Pb. #3: carrier concentration of 1.2×10^{20}/cm^3; addition of Pb I_2; 3 excess Pb.	#1(a): single crystal; p-type; prepared by slow cooling in evacuated and sealed quartz capsule; annealed in capsule for several days at 300°C. #1(b): p-type; annealed in evacuated and sealed quartz capsule for 8 to 10 hrs at 600°C. #2: n-type; prepared by powder metallurgy. #3: n-type; prepared same as #2. Six other specimens measured, some alloyed with Cℓ, Br, and I, with intermediate values. Also measured Pb Te + 1% Pb Se at 283 K.	A-1; B-1; C-1; D-1(2); F-4; G-3;	E. D. Devyatkova and I. A. Smirnov (1962).
F. S. Y. -Pb S	Libya; carrier concentration of 1.48×10^{17}/cm^3; very small traces of Ag and Cd.	3-5 big crystals.	A-1; B-1; C-1; D-1(2); E-1; F-4; G-3; O-9; Q-4; S-1, 2.	B. S. Farag, I. A. Smirnov, and Y. L. Yousef (1965).
. . . . .	Pb Te.	Graph of lattice thermal conductivity.	. . . . .	Yu. I. Ravich, I. A. Smirnov, and V. V. Tikhonov (1967).

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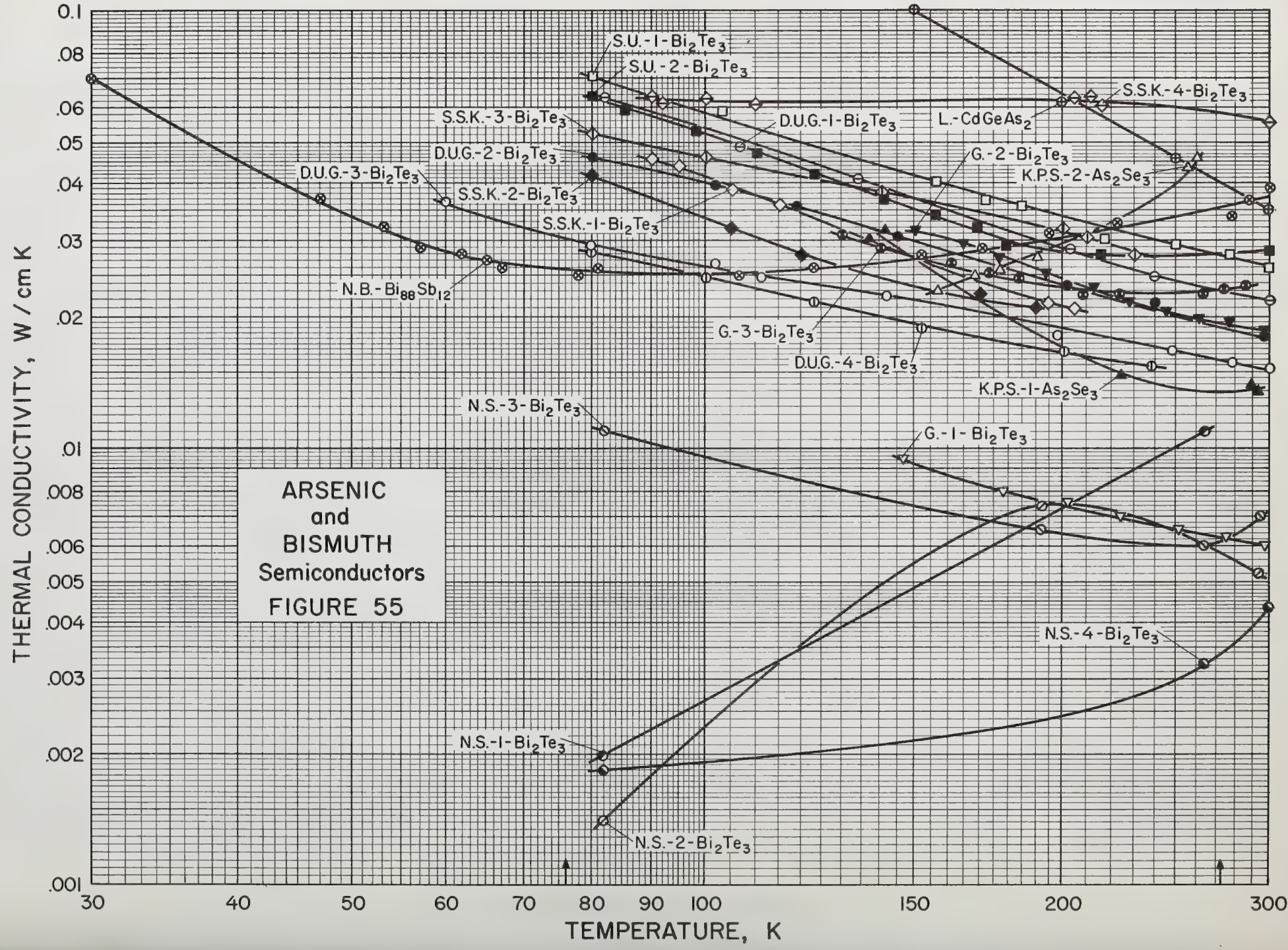

THERMAL CONDUCTIVITY, W / cm K
TEMPERATURE, K
0.1
.08
.06
.05
.04
.03
.02
.01
.008
.006
.005
.004
.003
.002
.001
30
40
50
60
70
80
90
100
150
200
300
S.U.-1-Bi2Te3
S.U.-2-Bi2Te3
S.S.K.-4-Bi2Te3
L.-CdGeAs2
S.S.K.-3-Bi2Te3
D.U.G.-1-Bi2Te3
G.-2-Bi2Te3
D.U.G.-2-Bi2Te3
K.P.S.-2-As2Se3
D.U.G.-3-Bi2Te3
S.S.K.-2-Bi2Te3
S.S.K.-1-Bi2Te3
N.B.-Bi88Sb12
G.-3-Bi2Te3
D.U.G.-4-Bi2Te3
K.P.S.-1-As2Se3
N.S.-3-Bi2Te3
G.-1-Bi2Te3
N.S.-4-Bi2Te3
N.S.-1-Bi2Te3
N.S.-2-Bi2Te3
ARSENIC
and
BISMUTH
Semiconductors
FIGURE 55

ARSENIC SEMICONDUCTORS

(See FIGURE 55)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	$As_2 Te_3$. #1: carrier concentration of holes 40 x 10^{18} /cm; doped with excess As p-type impurities. #2: carrier concentration of electrons 18 x 10^{18} /cm^3; doped with excess Te and I n-type impurities.	Prepared by vertical zone melting. #1: p-type; k = 0.027 at 300 K. #2: n-type; k = 0.025 at 300 K.	A-6; S-1, 2.	T. C. Harman, B. Paris, S. E. Miller, and H. L. Goering (1957).
L. -Cd Ge As_2	. . . . .	Also measured Zn Sn As_2, Zn Ge As_2, and Cd Sn As_2. Zn Sn As_2: at 100 K, k = 0.231; at 150 K, k = 0.162; at 200 K, k = 0.135; at 250 K, k = 0.113; at 300 K, k = 0.102. Zn Ge As_2: at 100 K, k = 0.246; at 200 K, k = 0.135; at 300 K, k = 0.0935. Cd Sn As_2; at 300 K, k = 0.103.	A-6; O-3.	P. Leroux-Hugon (1963).
K. P. S. -1, 2- $As_2 Se_3$	#1: $As_2 Se_3$. #2: $As_2 S_3$-$As_2 Se_3$.	#1: polycrystalline $As_2 Se_3$; density of 4.54 g/cm^3. #2: glass $As_2 S_3$-$As_2 Se_3$; density of 4.45 g/cm^3. $As_2 S_3$ gave the same results within 20% of #2.	A-1; B-1; C-1; D-1(2); F-4; G-3; O-1, 5; P-1; S-3.	B. T. Kolomiets, L. Payasova, and L. Shtourach (1965).

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	$Sb_2 Te_3$: carrier concentration of holes 70 x $10^{18}/cm^3$; doped with excess Sb p-type impurities.	$Sb_2 Te_3$; p-type; prepared by Bridgman and sintering-anneal techniques; k = 0.048 at 300 K.	A-6; S-1,2.	T.C.Harman, B. Paris, S.E. Miller, and H. L.Goering (1957).
. . . . .	$Sb_2 Te_3$: 99.999 Bi, American Smelting and Refining 99.999 Te, National Lead 99.999 Sb. #1: $Sb_2 Te_3$. #2: $Sb_2 Te_3$ + 28(mole) $Bi_2 Te_3$. #3: $Sb_2 Te_3$ + 44 $Bi_2 Te_3$.	Melted in vacuum, zone refined; melted stoichiometric proportions in quartz tubes; solidified by Bridgman technique at 6 mm/hr. Very coarse grains; (0001) plane within 10° of rod axis. At 300 K: #1, k = 0.045; #2, k = 0.030; #3, k = 0.023. Table of electronic and lattice thermal conductivity; graph of lattice thermal conductivity as function of composition of $Bi_2 Te_3$ - $Sb_2 Te_3$.	A-1; B-2; C-1; D-1; F-4; G-3; M-1,2; P-12; Q-3,4; S-1,2.	F.D.Rosi, B. Abeles, and R.V. Jensen (1959).
. . . . .	75(mole) $Sb_2 Te_3$ - 25 $Bi_2 Te_3$; excess Te.	Grown by Bridgman technique; p-type. k = 0.049 at 121 K; k = 0.027 at 202 K; k = 0.017 at 294 K.	A-4; B-1; C-3; D-1(3); F-4; G-3; M-1; O-1; P-1; S-1,2.	J.Rupprecht (1963).

BISMUTH SEMICONDUCTORS

(See FIGURE 55)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
G.-1, 2, 3- Bi_2 Te_3	#2: relatively impure. #3: relatively pure.	#1: cut from single crystal; p-type; rod axis perpendicular to basal plane. #2 and #3: cut from zone-refined bars, with faces perpendicular to direction of zoning and cleavage plane parallel to rod axis; n-type. #3 was nearly intrinsic. Three other specimens also measured. Graph of lattice thermal conductivity.	A-1; B-2; C-1; D-1(2); F-4; G-2; M-1; O-1, 6; P-1; R-1; S-1.	H. J. Goldsmid (1956).
S.U.-1, 2- Bi_2 Te_3	Prepared from Cerro de Pasco 99.999 Bi and American Smelting and Refining 99.999 Te. #1: carrier concentration of $2 \times 10^{19}/cm^3$. #2: carrier concentration of $3 \times 10^{17}/cm^3$.	Single crystals. #1: zone refined; p-type. #2: prepared by melting and mixing in high vacuum in Vycor ampule, and then suspended in crystal furnace, lowered through sharp temperature gradient in 24 hrs; n-type. Graphs of electronic and lattice thermal conductivity.	A-1; B-1; C-1; D-1(4); E-5, 8; F-2; G-2; O-1; P-2; R-1; S-1, 2.	C. B. Satterthwaite and R. W. Ure (1957).
. . . . .	#1: carrier concentration of holes $8 \times 10^{18}/cm^3$; excess Bi and Pb impurities. #2: carrier concentration of electrons $5 \times 10^{18}/cm^3$; excess of Te and I impurities.	Prepared by quenching, annealing, and zone melting. At 300 K, both specimens: k = 0.021.	A-6; S-1, 2.	T. C. Harman, B. Paris, S. E. Miller, and H. L. Goering (1957).
. . . . .	Bi_2 Te_3.	Calculated the thermal conductivity of Bi_2 Te_3 from thermal diffusivity measurements.	. . . . .	Y. Kanai and R. Nii (1959).
. . . . .	Bi_2 Te_3: 99.999 Bi, American Smelting and Refining 99.999 Te and Se, National Lead 99.999 Sb. #1: Bi_2 Te_3 + 6(mole) Sb_2 Te_3. #2: Bi_2 Te_3 + 12 Sb_2 Te_3. #3: Bi_2 Te_3 + 16 Sb_2 Te_3. #4: Bi_2 Te_3 + 29 Sb_2 Te_3. #5: Bi_2 Te_3 + 38 Sb_2 Te_3.	Melted in vacuum, zone refined; melted stoichometric proportions in quartz tubes; solidified by Bridgman technique at 6 mm/hr; p-type. Very coarse grains; (0001) plane within 10° of rod axis. At 300 K: #1, k = 0.025; #2, k = 0.026; #3, k = 0.025; #4, k = 0.020; #5, k = 0.023. Table of electronic and lattice thermal conductivity; graphs of lattice thermal conductivity as function of composition of Bi_2 Te_3 - Sb_2 Te_3 and Bi_2 Te_3 - Bi_2 Se_3.	A-1; B-2; C-1; D-1(2); F-4; G-3; M-1, 2; P-12; Q-3, 4; S-1, 2.	F. D. Rosi, B. Abeles, and R. V. Jensen (1959).

BISMUTH SEMICONDUCTORS (cont'd)

(See FIGURE 55)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	#1: $Bi_2 Se_3$. #1(a): 70 $Bi_2 Se_3$ - 30 $Bi_2 Te_3$. #2: $Bi_2 Te_3$.	Crushed to fine powder; blended to correct composition, compressed under pressure of 2-5 metric ton/cm^2 at 300°C; repeatedly reannealed at higher temperature. Cubic crystal; solid solution; small inclusions. At 280 K - #1: k = 0.0142; #1(a): k = 0.00835; #2: k = 0.0157. Specimens of intermediate composition also measured, with intermediate values.	O-3, 5; P-1; Q-3.	A. V. Ioffe and A. F. Ioffe (1960).
. . . . .	$Bi_2 Te_3$.	Graph of lattice thermal conductivity.	. . . . .	A. C. Beer and R. T. Bate (1962).
. . . . .	90(mole) $Bi_2 Te_3$ - 10 $Bi_2 Se_3$; doped with Br.	Grown by Bridgman technique; n-type. k = 0.040 at 116 K; k = 0.023 at 201 K; k = 0.017 at 293 K.	A-4; B-1; C-3; D-1(3); F-4; G-3; M-1; O-1; P-1; S-1, 2.	J. Rupprecht (1963).
N. B-$Bi_{88} Sb_{12}$	$Bi_{88} Sb_{12}$ + 0.5 Pb.	Single crystal; rod axis parallel to c-axis.	A-1; B-1; C-1; D-1(2); E-5, 8; F-4; G-3; M-1; O-1; P-1; R-1; S-2.	B. Noren and O. Beckman (1964).
. . . . .	$Bi_2 Te_3$.	Graph of lattice thermal resistivity of $Bi_2 Te_3$	. . . . .	E. A. Gurieva, V. A. Kutasov, and I. A. Smirnov (1965); see also E. A. Guriev, A. I. Zaslovskii, V. A. Kutasov, and I. A. Smirnov (1965).
N. S. -1, 2, 3, 4 - $Bi_2 Te_3$	Prepared from Johnson, Matthey pure Bi, Te, and Gd; 0.1 9atomic) excess Te. #1: undoped. #2: doped with 0.01 Gd. #3: doped with 0.06 Gd. #4: doped with 0.14 Gd.	Prepared by quenching from above the melting point, then annealing. n-type. #2-#4: doped specimens, quenched and annealed again. One other specimen with 0.17 (atomic) Gd also measured.	A-1; B-1; C-1; D-1(2); F-2; G-3; M-1; O-1; P-1, 12; S-1, 2.	K. S. V. L. Narasimhan and K. P. Sinha (1965).

BISMUTH SEMICONDUCTORS (cont'd)

(See FIGURE 55)

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
D.U.G. -1, 2, 3, 4 - $Bi_2 Te_3$	Prepared from 99.999 purity elements. #1: carrier concentration of $2.6 \times 10^{19}/cm^3$; doped with Bi. #2: carrier concentration of $3.3 \times 10^{19}/cm^3$; $Bi_2 Te_3$ + 2(mole) $Bi_2 Se_3$. #3: carrier concentration of $2.1 \times 10^{19}/cm^3$; $Bi_2 Te_3$ + 10(mole) $Bi_2 Se_3$; doped with I. #4: carrier concentration of $4.3 \times 10^{18}/cm^3$, $Bi_2 Te_3$ + 10(mole) $Bi_2 Se_3$; doped with I.	Prepared by sealing stoichiometric proportions in evacuated graphite-coated vycor tubes; thoroughly mixed in rocking furnace above the melting point; air or water quenched. Few large crystals; rod axis parallel to cleavage plane; cut with spark cutter. #1: single crystal; p-type; prepared by single zone technique. #2: nearly single crystal; no grains. #3: prepared by Bridgman technique; 6 nearly single crystal grains. #4: prepared by single zone pass; single crystal. Three other specimens also measured. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-1(2); F-4; G-3; O-3; P-2, 3, 8, 11, 12; R-1; S-1, 2.	D.H. Damon, R.W. Ure, and J. Gersi (1967).
S.S.K. -1, 2, 3, 4- $Bi_2 Te_3$	#1: stoichiometric. #2: doped with Te; carrier concentration of $10^{18}/cm^3$. #3: doped with Br. #4: doped with I.	Prepared by directed crystallization method from the melt. #1: p-type. #2: n-type. #3: n-type. #4: n-type. Graph of lattice thermal resistance.	A-1; B-1; C-1; D-1(2); E-1; F-4; G-3; L-1; M-1; N-5; R-1; S-1, 2, 5.	I. A. Smirnov, E. V. Shadrichev, and V. A. Kutasov (1970).

TELLURIUM SEMICONDUCTORS
(See FIGURE 56a)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Te + impurities.	See TELLURIUM under "Elements".	. . . . .	E. D. Devyatkova, B. Ya. Moizhes, and I. A. Smirnov (1959).
P.S.S.-1,2-$In_2 Te_3$	$In_2 Te_3$.	α-modification structure. #1: four specimens with identical results; one was cast, coarse-grained, annealed 50 hrs at 400°C; one was cast, coarse-grained, unannealed; one was annealed 50 hrs at 300°C; one was further annealed 50 hrs at 400°C. #2: cast, coarse-grained; pressed; annealed 50 hrs. at 300°C.	A-1; B-1; C-1; D-1(2); E-1; F-4; G-3; O-1; P-1; R-3.	V. A. Petrusevich, V. M. Sergeeva, and I. A. Smirnov (1961).

SELENIUM SEMIMETAL

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Se + Tℓ; prepared by melting together 99.996 Se, and $Tℓ_2$ Se. #1: 1.5 (weight) Tℓ; #2: 1 Tℓ; #3: 0.75 Tℓ; #4: 0.5 Tℓ; #5: 0.25 Tℓ; #6: 0.0125 Tℓ; #7: 0.05 Tℓ.	Prepared by melting together in vacuum. At 20°C: #1, k = 0.026; #2, k = 0.024; #3, k = 0.02; #4, K = 0.02; #5, k = 0.016; #6, k = 0.017; #7, k = 0.013.	A-7; B-4; C-1; D-1(2); F-3; G-3; O-3; P-2, 4; Q-3; S-1.	G. B. Abdullaev, M. I. Aliev, and S. A. Akhundova (1961).

LANTHANUM SEMIMETALS

(See FIGURES 56a and 56b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
Go.-LaTe, LaSe, LaS	Starting materials: electron-beam refined La, V-5 grade S and Se, and Zone-melt purified Te. Carrier concentration at 300 K: LaTe, $2.55 \times 10^{22}/cm^3$; LaSe, $2.1 \times 10^{22}/cm^3$; LaS, $2.2 \times 10^{22}/cm^3$.	Synthesized from the elements; prepared by pressing of powders under pressure of 8000 kg/cm^2; sintered 1-2 hrs at 1600-1800°C in vacuum. Structure of NaCl-type; LaTe had violet-red color; LaS and LaSe had gold color. Graph of lattice thermal conductivity. Density: LaTe, 6.55 g/cm^3; LaSe, 6.34 g/cm^3; LaS, 5.75 g/cm^3.	A-1; B-2; C-1; D-1(2); E-1; F-4; G-3; L-1; M-1; O-1; P-1; Q-1; S-1, 2, 5.	A. V. Golubkov, E. D. Devyatkova, V. P. Zhuze, V. M. Sergeeva, and I. A. Smirnov (1966).
G.-LaSb	Prepared from 99.99 La and Sb; La impurities of 0.1 Ce and O_2, 0.05 Cu and Nd, 0.005 Pr, and 0.008 Fe; stoichiometric to within 1%; carrier concentration of $2.5 \times 10^{21}/cm^3$.	Prepared by remelting in electron-beam furnace; coarse-grained ingots grown by directional crystallization method in induction furnace; n-type.	A-1; B-1; C-1; D-1(2); F-4; G-3; M-1; N-5; O-1; P-1; R-1; S-1, 2, 6.	E. V. Goncharova, V. P. Zhuze, V. V. Zhdanova, T. B. Zhukova, I. A. Smirnov, and E. V. Shadrichev (1968).

TITANIUM SEMIMETALS

(See FIGURE 56b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
R.W.-1, 2, 3-TiC	Linde; metallic impurity of carbide crystals <0.1(atomic); <0.01(weight) O_2 and N_2. #1: $TiC_{0.83}$. #2: $TiC_{0.90}$. #3: $TiC_{0.96}$.	Cut from single-crystal boules grown by arc-Verneuil process; crystallized in rocksalt structure; some low-angle boundaries and grown-in dislocations present at density of $10^6/cm^2$. #1: ground surface. #2: cleaned surface. #3: ground surface. Two other specimens also measured, with intermediate results. One specimen also measured to study effect of ground surfaces. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-1(2); G-3; L-1; M-1; O-3; P-2, 3, 4, 11; Q-1.	L.G. Radosevich and W.S. Williams (1969a) and (1969b).

ZIRCONIUM SEMIMETALS

(See FIGURE 56b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
R.W.-Zr C	Linde; Zr $C_{0.88}$; metallic impurity of carbide crystal <0.1(atomic); <0.01(weight) O_2 and N_2.	Cleaved from single-crystal boule grown by arc-Verneuil process; crystallized in rock-salt structure; some low-angle boundaries and grown-in dislocations at density of 10^6 /cm^2. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-1; G-3; L-1; M-1; O-3; P-2, 3, 4, 11; Q-1.	L.G. Radosevich and W.S. Williams (1969a).
M.S.-ZrC	Wah Chang Corp.; 87.1 Zr, 11.2 total C, 0.6 free C, 0.6 O_2, <200 ppm Hf, <100 ppm Cr, Mo, and Nb, <30 ppm Ba, Co, K, Sr, and Ti, <10 ppm Aℓ, Bi, Cu, Ni, Pb, Si, and Sn, <3 ppm Ag, B, Ca, Li, Mn, and Na, <1 ppm Be and Mg.	Hot-pressed at 3000 K for 10 min at 225 atm. Density of 6.26 g/cm^3. Calculated from thermal diffusivity measurements. Disc axis parallel to longitudinal axis of hot pressed cylinder.	A-2; B-4; L-1; M-1; P-1.	B.H. Morrison and L.L. Sturgess (1970).

NIOBIUM SEMIMETALS

(See FIGURE 56b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
R. W. (1)-NbC	Linde; $NbC_{0.76}$; metallic impurity content of carbide crystals <0.1(atomic); <0.01(weight) O_2 and N_2.	Cleaved from single-crystal boule grown by arc-Verneuil process; crystallized in rock-salt structure; some low-angle boundaries and grown-in dislocations at density of 10^6 /cm^2. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-1; G-3; L-1; M-1; O-3; P-2, 3, 4, 11; Q-1.	L. G. Radosevich and W. S. Williams (1969a).
R. W. (2)-1, 1(S)-NbC	Ventron Electronics; $NbC_{0.96}$.	Measured in both the normal and superconducting (S) states. T_c = 9.8 K. Values in superconducting state below 4 K; 0.30 at 3.5 K; 0.31 at 3.1 K; 0.32 at 2.9 K; 0.28 at 2.5 K; 0.204 at 2 K; 0.109 at 1.6 K. Graph of electronic and lattice thermal conductivity. Graph of ratio of lattice thermal conductivity in superconducting and normal states as a function of reduced temperatures.	A-1; B-1; C-1; D-1; G-3; L-1; M-1; N-3; O-3; P-2, 3, 4, 11; Q-1.	L. G. Radosevich and W. S. Williams (1969c).
M. S. -NbC	Wah Chang Corp.; 88.4 Nb, 11.2 total C, <500 ppm free C, 0.13 O_2, 2000 ppm W, 500 ppm Ta, 200 ppm Ti, 170 ppm N_2, 50 ppm Cr, Mo, and Zr, <30 ppm Ba, Co, K, and Sr, <10 ppm Aℓ, Bi, Cu, Ni, Pb, Si, Sn, and V, <3 ppm Ag, B, Ca, Li, Mn, and Na, <1 ppm Be and Mg.	Hot-pressed at 3300 K for 10 min at 225 atm. Density of 7.52 g/cm^3. Disc axis parallel to longitudinal axis of hot pressed cylinder.	A-2; B-4; L-1; M-1; P-1.	B. H. Morrison and L. L. Sturgess (1970).

PRASEODYMIUM SEMIMETALS

(See FIGURE 56b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
D.-PrS, PrSe, PrTe	Starting materials: praseodymium, 0.5 La, 0.04 Cu, 0.03 Fe, 0.01 Ca; grade V-5 sulfur; high-purity selenium; zone-melted tellurium.	Prepared by briquetting powders under 8000 kg/cm^2; subsequently annealed in vacuum or inert atmosphere 1-2 hrs at 1600-1800°C. PrS: golden-yellow color. PrSe: reddish color. PrTe: violet-blue color. NaCℓ structure. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-1(2); E-1; F-4; G-3; L-1; M-1; O-3; Q-1; S-1, 2, 5.	E. D. Devyatkova, V. P. Zhuze, A. V. Golubkov, V. M. Sergeeva, and I. A. Smirnov (1964).

SAMARIUM SEMIMETAL

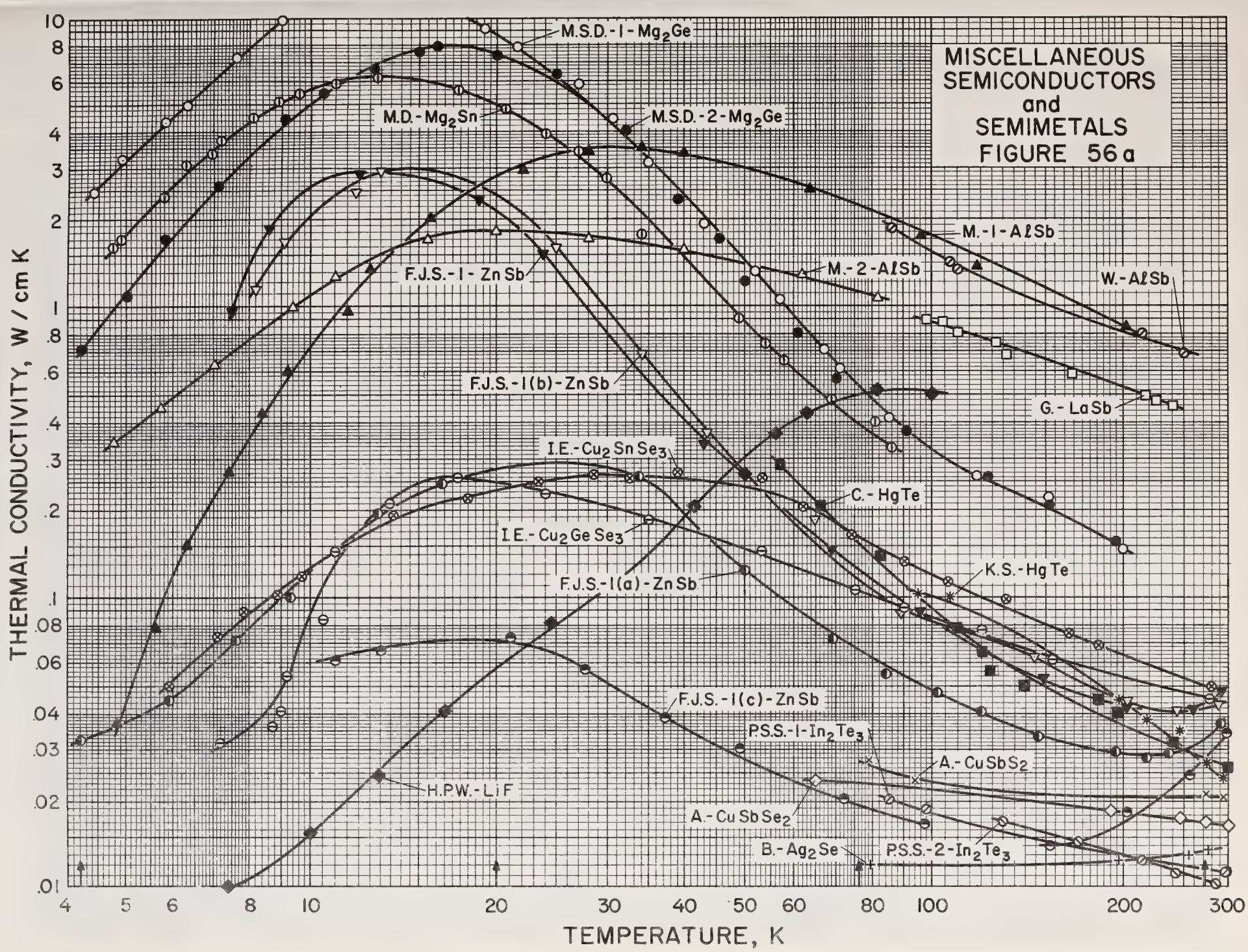
See FIGURE 56b)

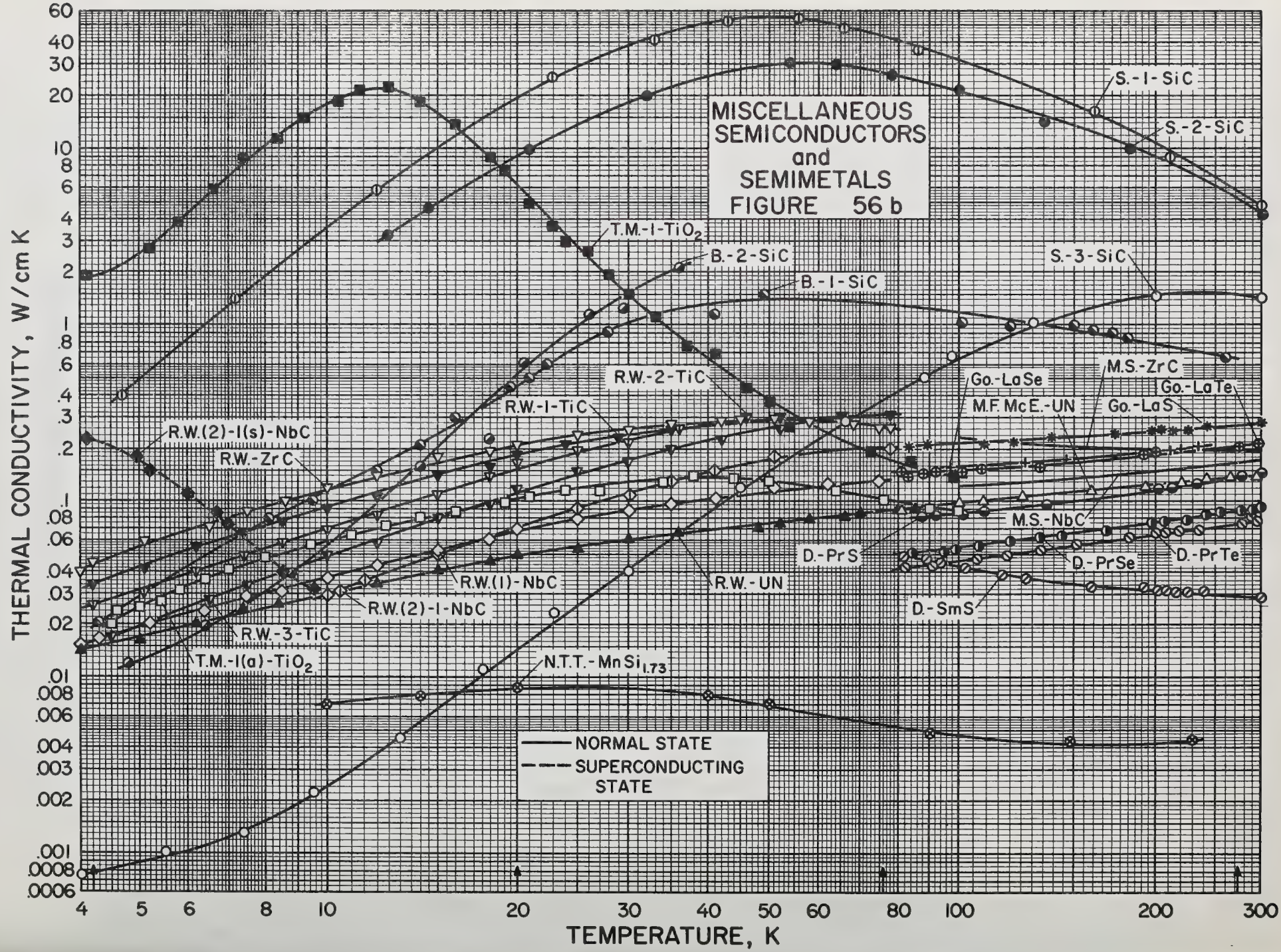
CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
D. -SmS	Starting materials: samarium, 0.5 Eu, 0.18 Ca, 0.02 Gd, 0.01 Nd and Y; grade V-5 sulfur.	Samarium sulfide; prepared by briquetting powders under 8000 kg/cm^2; subsequently annealed in vacuum or inert atmosphere 1-2 hrs at 1600-1800°C; NaCl structure. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-1(2); E-1; F-4; G-3; L-1; M-1; O-3; Q-1; S-1, 2, 5.	E. D. Devyatkova, V. P. Zhuze, A. V. Golubkov, V. M. Sergeeva, and I. A. Smirnov

URANIUM SEMIMETALS

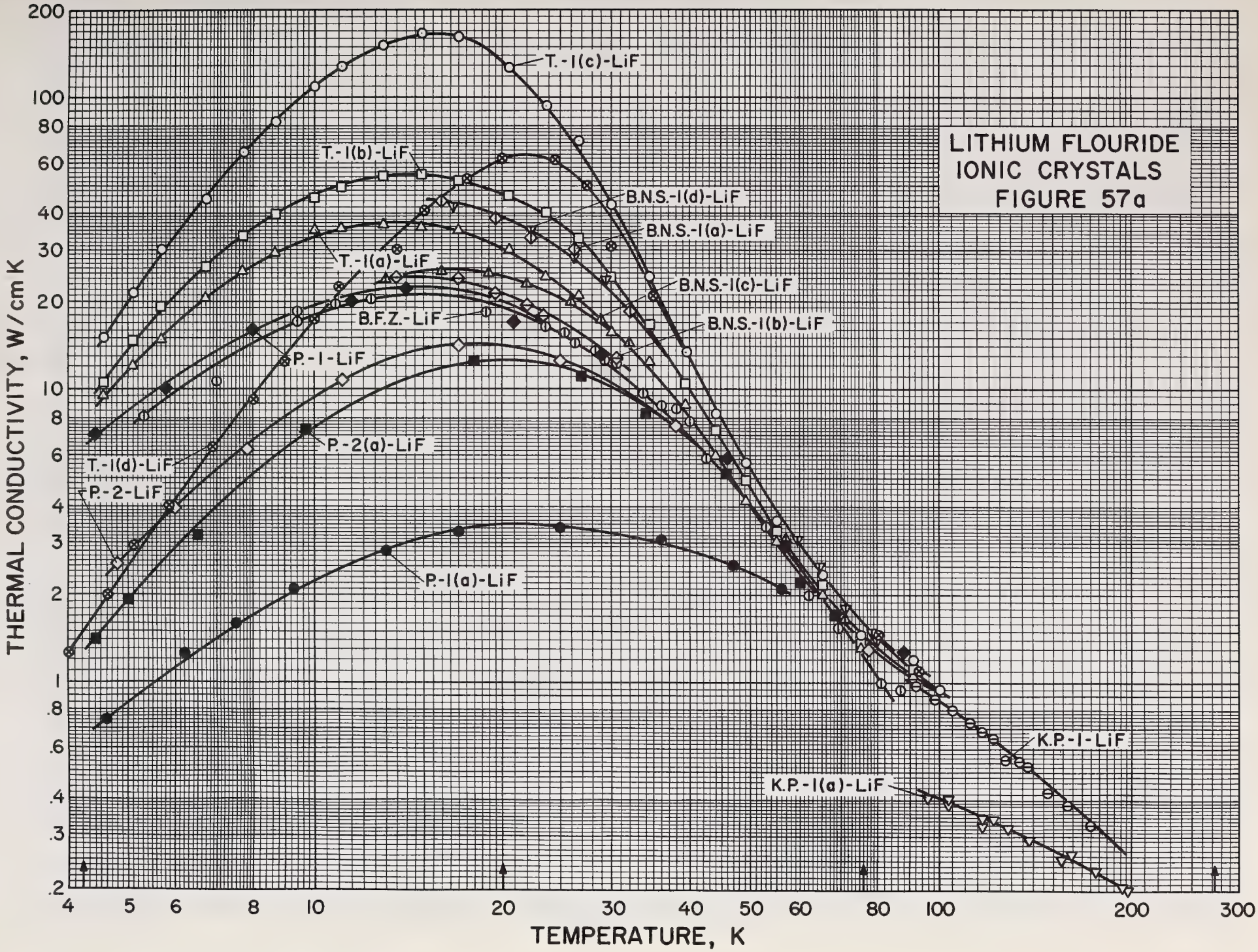
(See FIGURE 56b)

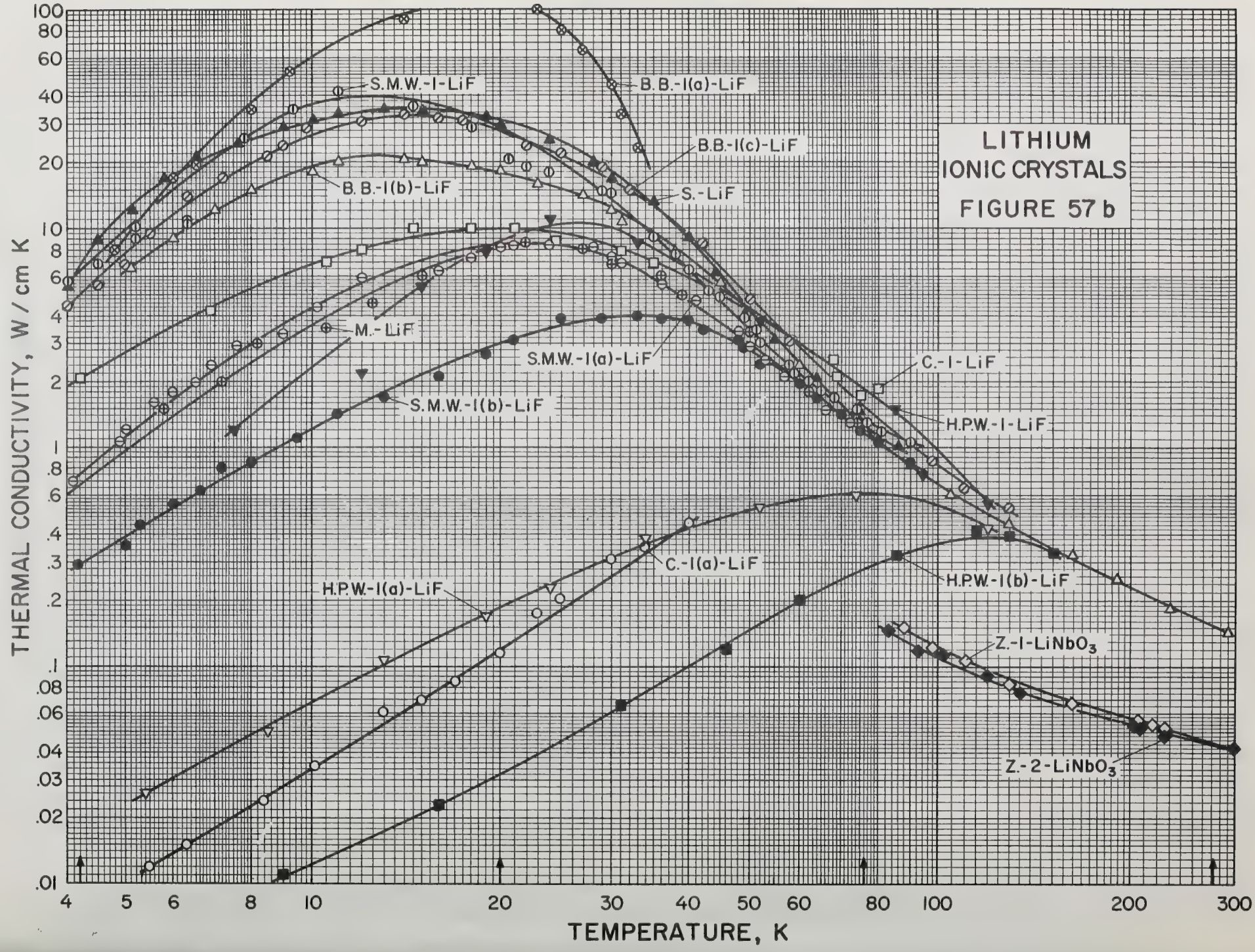
CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	UC: 0.005(weight) O_2. US: 0.30$_2$. UP: 0.13 O_2, 0.09 N_2.	UC: uranium monocarbide; prepared by arc-melting; k = 0.236 at room temperature, calculated from thermal diffusivity measurements; corrected to theoretical density, 99% theoretical density. US: uranium monosulfide; prepared by cold-pressing and sintering at 1800°C; k = 0.082. UP: uranium monophosphide; prepared by hot-pressing; k = 0.125 at room temperature; corrected to theoretical density, 93% theoretical density; 1% second-phase. Graph of electronic thermal conductivity.	L-1; M-1; O-1; P-2, 5.	J. B. Moser and O. L. Kruger (1967).
R. W. -UN	<1(volume) UO_2; RRR(25) = 24.9.	Transition temperature of 53 K. Graph of electronic and lattice thermal conductivity.	L-1; M-1; O-1; P-2, 5, 10; Q-1.	L. G. Radosevich and W. S. Williams (1969).
M. F. McE. -UN	Same specimen as R. W. -UN.	Pressed, sintered nitrogen for 3/4 hr at 2600 K; annealed 8.5 hrs at 2500 K; density of 13.6 g/cm^3 (97% theoretical). Grain size of 40μ; microhardness 659 mm^2/kg (DPH) at 25 gm-load. Data corrected to theoretical density. Graph of electronic and lattice thermal conductivity.	A-1; B-1; C-1; D-1(2); E-2; F-1; G-3; L-1; M-1, 6; O-1, 3; S-1, 2.	J. P. Moore, W. Fulkerson, and D. L. McElroy (1970).

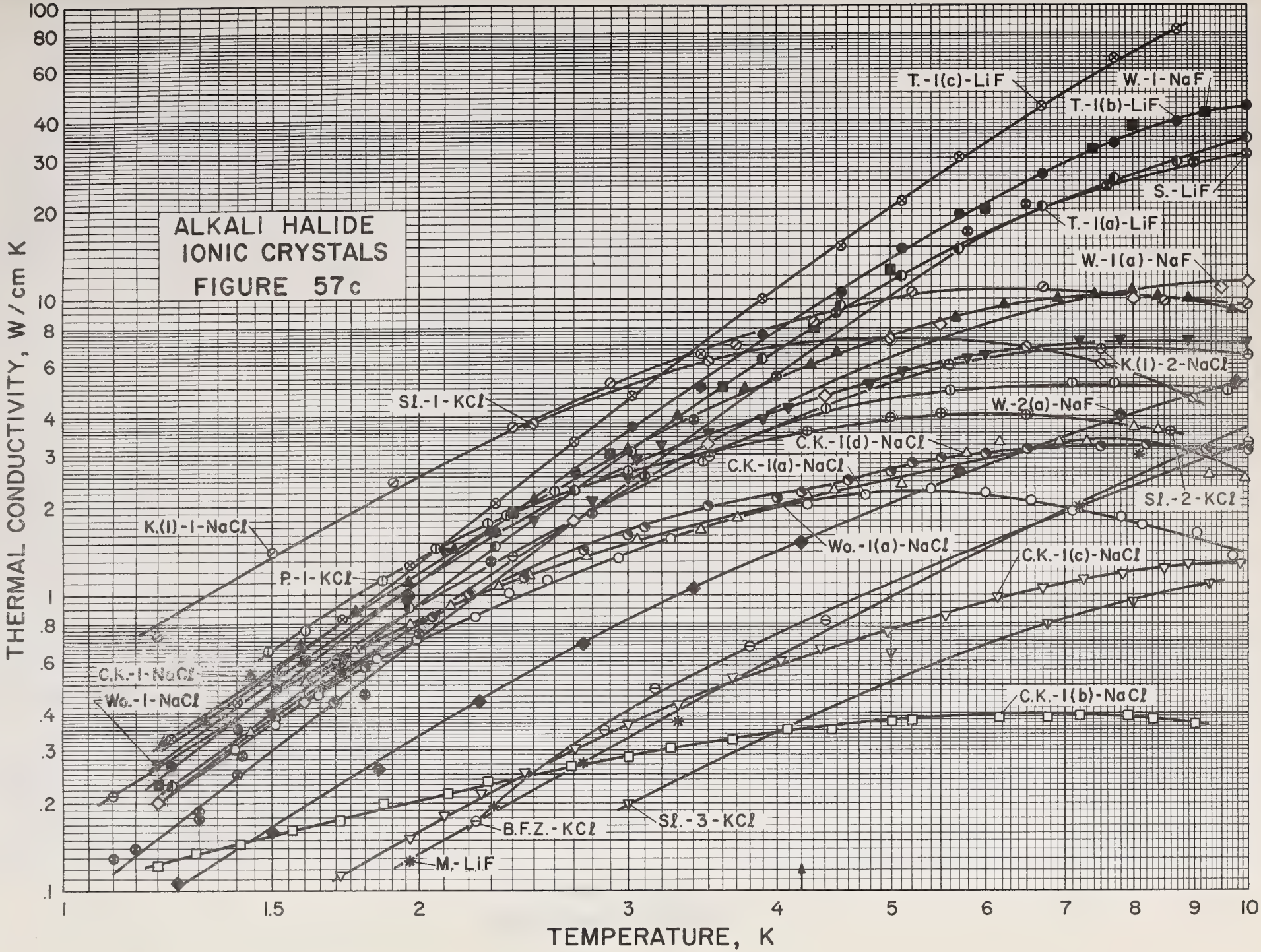

MISCELLANEOUS
SEMICONDUCTORS
and
SEMIMETALS
FIGURE 56a
THERMAL CONDUCTIVITY, W / cm K
TEMPERATURE, K
M.S.D.-1-Mg2Ge
M.D.-Mg2Sn
M.S.D.-2-Mg2Ge
M.-1-AlSb
M.-2-AlSb
W.-AlSb
F.J.S.-1-ZnSb
F.J.S.-1(b)-ZnSb
G.-LaSb
I.E.-Cu2SnSe3
C.-HgTe
I.E.-Cu2GeSe3
K.S.-HgTe
F.J.S.-1(a)-ZnSb
F.J.S.-1(c)-ZnSb
P.S.S.-1-In2Te3
A.-CuSbS2
H.P.W.-LiF
A.-CuSbSe2
B.-Ag2Se
P.S.S.-2-In2Te3


MISCELLANEOUS
SEMICONDUCTORS
and
SEMIMETALS
FIGURE 56 b
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
S.-1-SiC
S.-2-SiC
S.-3-SiC
T.M.-1-TiO2
B.-2-SiC
B.-1-SiC
R.W.-2-TiC
R.W.-1-TiC
R.W.(2)-1(s)-NbC
R.W.-ZrC
Go.-LaSe
M.S.-ZrC
Go.-LaTe
M.F. McE.-UN
Go.-LaS
M.S.-NbC
D.-PrS
D.-PrSe
D.-PrTe
R.W.(1)-NbC
R.W.-UN
R.W.(2)-1-NbC
D.-SmS
R.W.-3-TiC
T.M.-1(a)-TiO2
N.T.T.-MnSi1.73
NORMAL STATE
SUPERCONDUCTING STATE

3.4. IONIC AND VALENCE CRYSTALS AND MINERALS


LITHIUM FLOURIDE
IONIC CRYSTALS
FIGURE 57a
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
T.-I(c)-LiF
T.-I(b)-LiF
B.N.S.-I(d)-LiF
B.N.S.-I(a)-LiF
T.-I(a)-LiF
B.N.S.-I(c)-LiF
B.F.Z.-LiF
B.N.S.-I(b)-LiF
P.-I-LiF
P.-2(a)-LiF
T.-I(d)-LiF
P.-2-LiF
P.-I(a)-LiF
K.P.-I-LiF
K.P.-I(a)-LiF
200
100
80
60
40
30
20
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
4
5
6
8
10
20
30
40
50
60
80
100
200
300


LITHIUM
IONIC CRYSTALS
FIGURE 57 b
THERMAL CONDUCTIVITY, W / cm K
TEMPERATURE, K
100
80
60
40
30
20
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
.01
4
5
6
8
10
20
30
40
50
60
80
100
200
300
S.M.W.-I-LiF
B.B.-I(a)-LiF
B.B.-I(c)-LiF
B.B.-I(b)-LiF
S.-LiF
M.-LiF
S.M.W.-I(a)-LiF
S.M.W.-I(b)-LiF
C.-I-LiF
H.P.W.-I-LiF
C.-I(a)-LiF
H.P.W.-I(a)-LiF
H.P.W.-I(b)-LiF
Z.-I-LiNbO3
Z.-2-LiNbO3


ALKALI HALIDE
IONIC CRYSTALS
FIGURE 57c
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
100
80
60
40
30
20
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
1
1.5
2
3
4
5
6
7
8
9
10
T.-I(c)-LiF
W.-I-NaF
T.-I(b)-LiF
S.-LiF
T.-I(a)-LiF
W.-I(a)-NaF
K.(I)-2-NaCl
W.-2(a)-NaF
C.K.-I(d)-NaCl
C.K.-I(a)-NaCl
Sl.-2-KCl
Sl.-I-KCl
K.(I)-I-NaCl
Wo.-I(a)-NaCl
P.-I-KCl
C.K.-I(c)-NaCl
C.K.-I-NaCl
Wo.-I-NaCl
C.K.-I(b)-NaCl
B.F.Z.-KCl
Sl.-3-KCl
M.-LiF

LITHIUM IONIC CRYSTALS

(See FIGURES 57a-57c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
B. F. Z. -LiF	Harshaw Chemical Co.; <0.001 Mg, smaller concentrations of Aℓ, Fe, and Si.	. . . . .	A-1; B-1; C-1; D-3(2) E-4; F-4; G-2; O-3; P-2, 8.	R. Berman, E. L. Foster, and J. M. Ziman (1956).
C. -1, 1(a)-LiF	Harshaw Chemical Co.	Cleaved from single crystals; wrapped in aluminum foil. #1: unirradiated. #1(a): irradiated at 40°C by ^{60}Co γ-rays to total dose of 20.885×10^8 R. Speciman also irradiated at intermediate doses, with intermediate results. Graph of added resistivity shown for five thermal neutron irradiation dosages of up to 5.23×10^{17} neutrons/cm^2.	A-1; B-1; C-1; D-3(2); G-2; O-3; P-2, 3, 5, 9, 13.	A. F. Cohen (1958c).
S. M. W. -1, 1(a), 1(b)-LiF	Harshaw Chemical Co.	Cleaved along (100) planes. #1: annealed 2.5 hrs at 830°C, cooled at rate of 1°/min to 200°C, cooled more slowly to room temperature. Density of etch pits about 3×10^4 pits/cm^2. #1(a): reduced 2.4% by compression at 25°C; density of etch pits 1.8×10^7 pits/cm^2. #1(c): reduced 4.0% by compression at 180°C; density of etch pits 4.6×10^7 pits/cm^2. A specimen reduced by 2.6% in length, annealed 21 hrs at 620°C, also measured; results indistinguishable from #1. Also results on cleaved, unannealed specimen were substantially identical to B. F. Z. -LiF.	A-1; B-1; C-1; D-1(2); G-3; O-3, 5; P-2, 3, 9.	R. L. Sproull, M. Moss, and H. Weinstock (1959).
B. N. S. -1(a), 1(b), 1(c), 1(d)-LiF	Capenhurst Separation Plant, UKAEA. #1(a): LiF + 4.7 ^{6}Li; few hundred ppm Aℓ, Sn, and Zn. #1(b): LiF + 25.0 ^{6}Li; 100 ppm Aℓ and Fe, 50 ppm Sn. #1(c): LiF + 90.4 ^{6}Li; 100-200 ppm Aℓ and Sn. #1(d): LiF + 96.25 ^{6}Li; 100 ppm Aℓ and Fe.	Prepared by mixing natural LiF (^{6}Li concentration 7.4%) and 90% material; vacuum dried and crystallized in graphite crucibles by Stockbarger technique; selected portion regrown as rods; cooled at 1 mm/hr. Three other specimens with intermediate concentrations of ^{6}Li, including a natural crystal with 7.4% ^{6}Li which had values between #1(a) and #1(b), also measured. Graph of thermal conductivity at 30 K as a function of ^{6}Li concentration.	A-1; B-1; C-1; D-3(2); E-4; F-4; G-2; O-2, 3; P-2, 3, 4, 5, 8.	R. Berman, P. T. Nettley, F. W. Sheard, A. N. Spencer, R. W. H. Stevenson, and J. M. Ziman (1959).

LITHIUM IONIC CRYSTALS (cont'd)

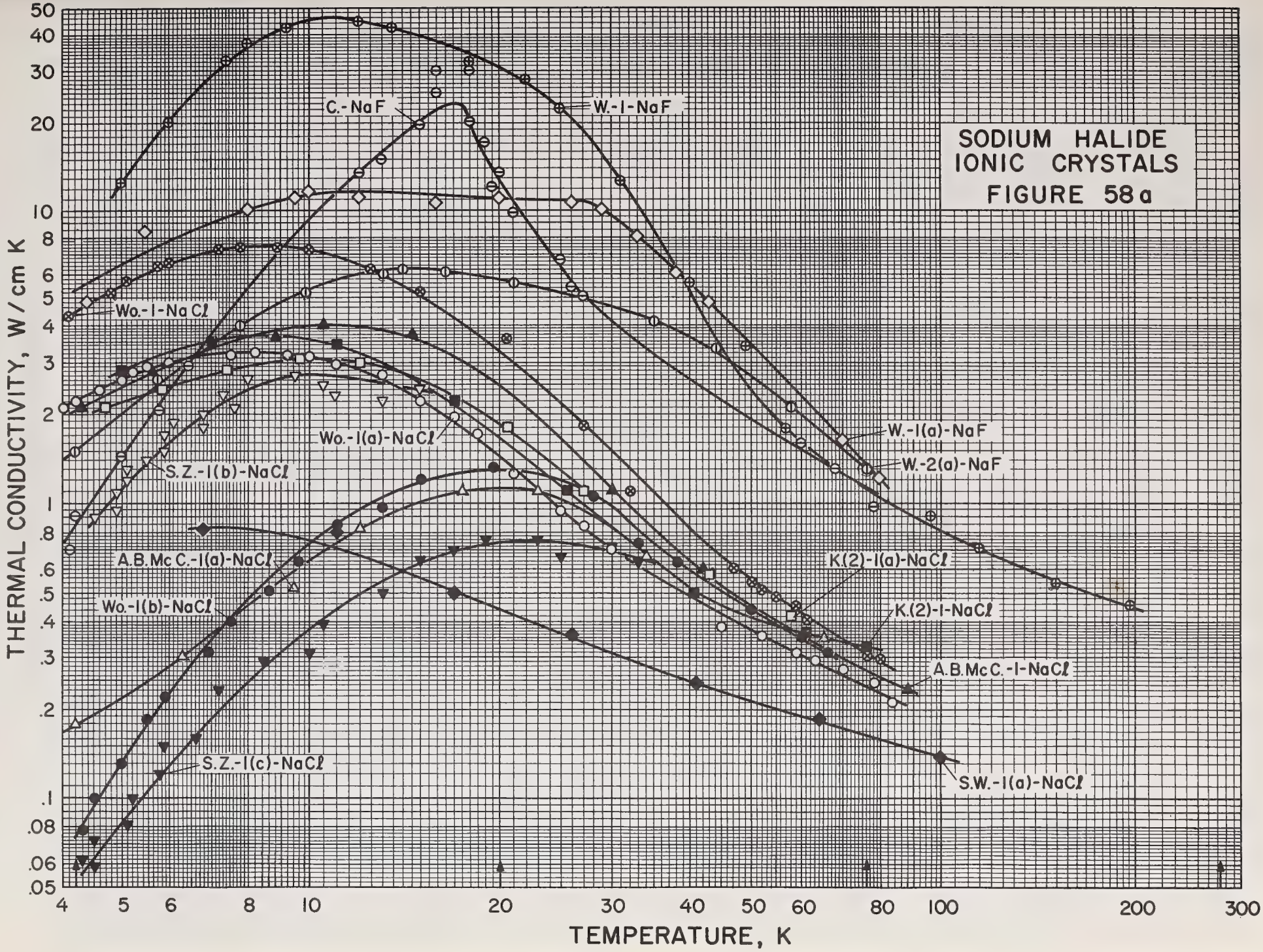
(See FIGURES 57a-57c)

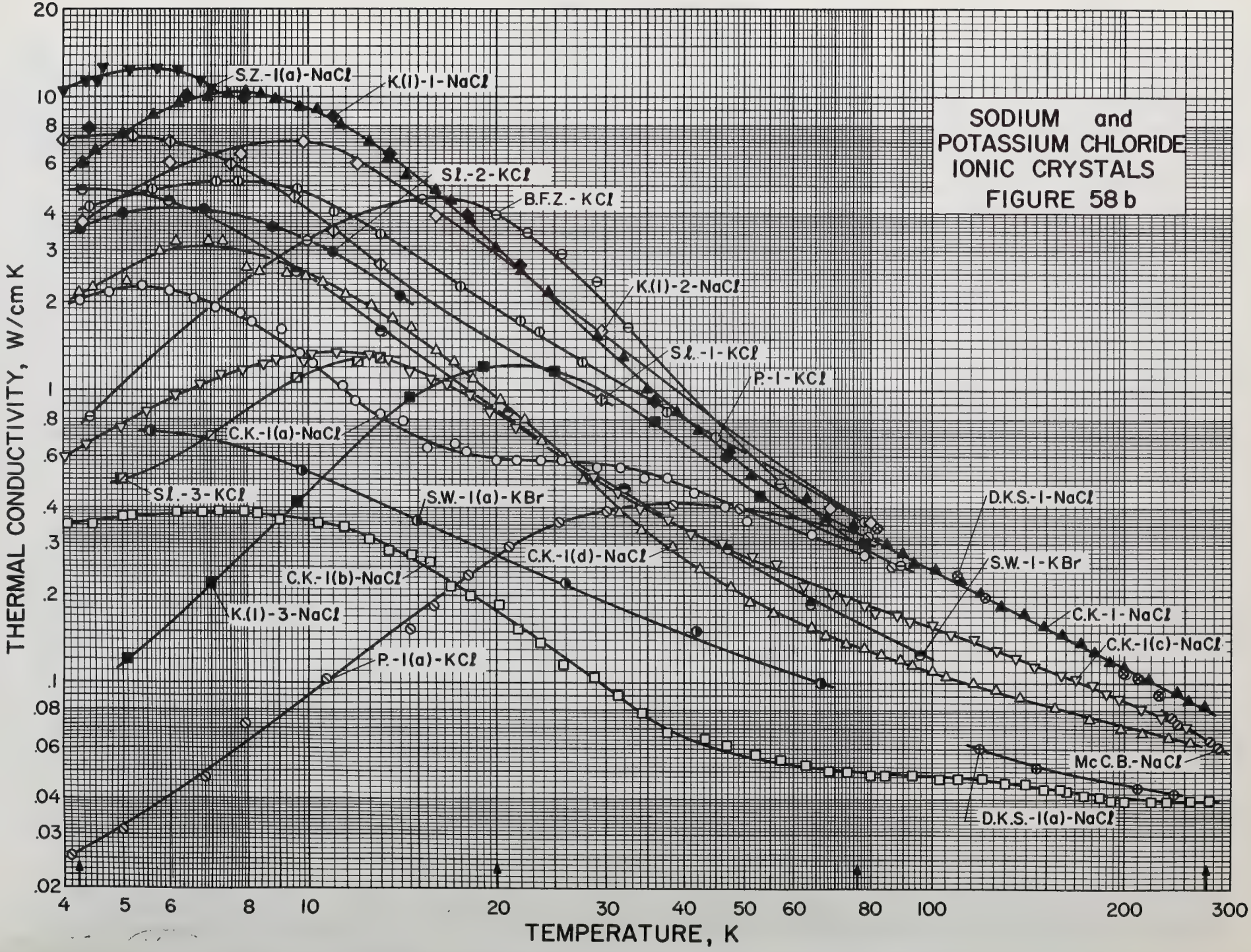
CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
P. -1, 1(a), 2, 2(a)-LiF	Harshaw LiF. #1(a): number of F-centers 2 x 10^{18} /cm^3.	Cleaved; annealed 3 hrs at 1100 K; cooled at rate of 1°C/min to 500 K, then more slowly to room temperature. #1: specimen size of 6.7 x 7.3 x 40 mm. #1(a): specimen #1 exposed to successive irradiations at room temperature by 60 kv x-rays filtered by 2 mm Aℓ and 1.5 Mev γ-rays; number of F-centers 2 x 10^{18}/cm^3. Specimen measured after six successive treatments produced lower number of F-centers, with intermediate results. #2: specimen size of 0.74 x 0.79 x 40 mm. #2(a): specimen #2 after sandblasting and annealing.	A-1; B-1; C-1; D-1(2); G-2; O-2, 3, 5; P-2, 5, 8, 9, 14.	R. O. Pohl (1960).
M. -LiF	Harshaw Chemical Co.	Cleavage system is {100}. Deformed at temperature of 175°C; height reduced 2.7%; maximum increase at middle of 4.4%; blank cleaved in two, and average deformation of 4.2%. Another crystal quenched from 600°C into liquid $CC\ell_4$, dislocation density of 10^{18}/cm^2; results same as those shown for M. -LiF. Specimens with rod axis parallel and perpendicular to edge dislocations have identical results.	A-1; B-1; C-1; D-3(2); E-3, 4, 5; F-4; G-3; O-3; P-3, 5, 9.	M. Moss (1965).
B. B. -1(a), 1(b), 1(c)-LiF	#1(a): 0.02 ^{6}Li. #1(b): 50.1 ^{6}Li. #1(c): natural abundance, 7.4 ^{6}Li.	Annealed in vacuum 2 hrs at 770°C; cooled slowly for 12 hrs; sand-blasted. #1(b): dislocation density of 1.2 x 10^6/cm^2. #1(c): dislocation density of 1.6 x 10^6/cm^2. Five other specimens also measured, with intermediate results.	A-1; B-1; C-1; D-1(3); E-5; F-4; G-2; O-2, 3, 9; P-3, 5, 8.	R. Berman and J. C. F. Brock (1965).
. . . . .	. . . . .	Graph of change in thermal conductivity of LiF as a function of neutron irradiation.	. . . . .	L. F. Vorozheikina, D. D. Igitkhanishvili, N. G. Politov, and V. G. Kvachadzę (1965).

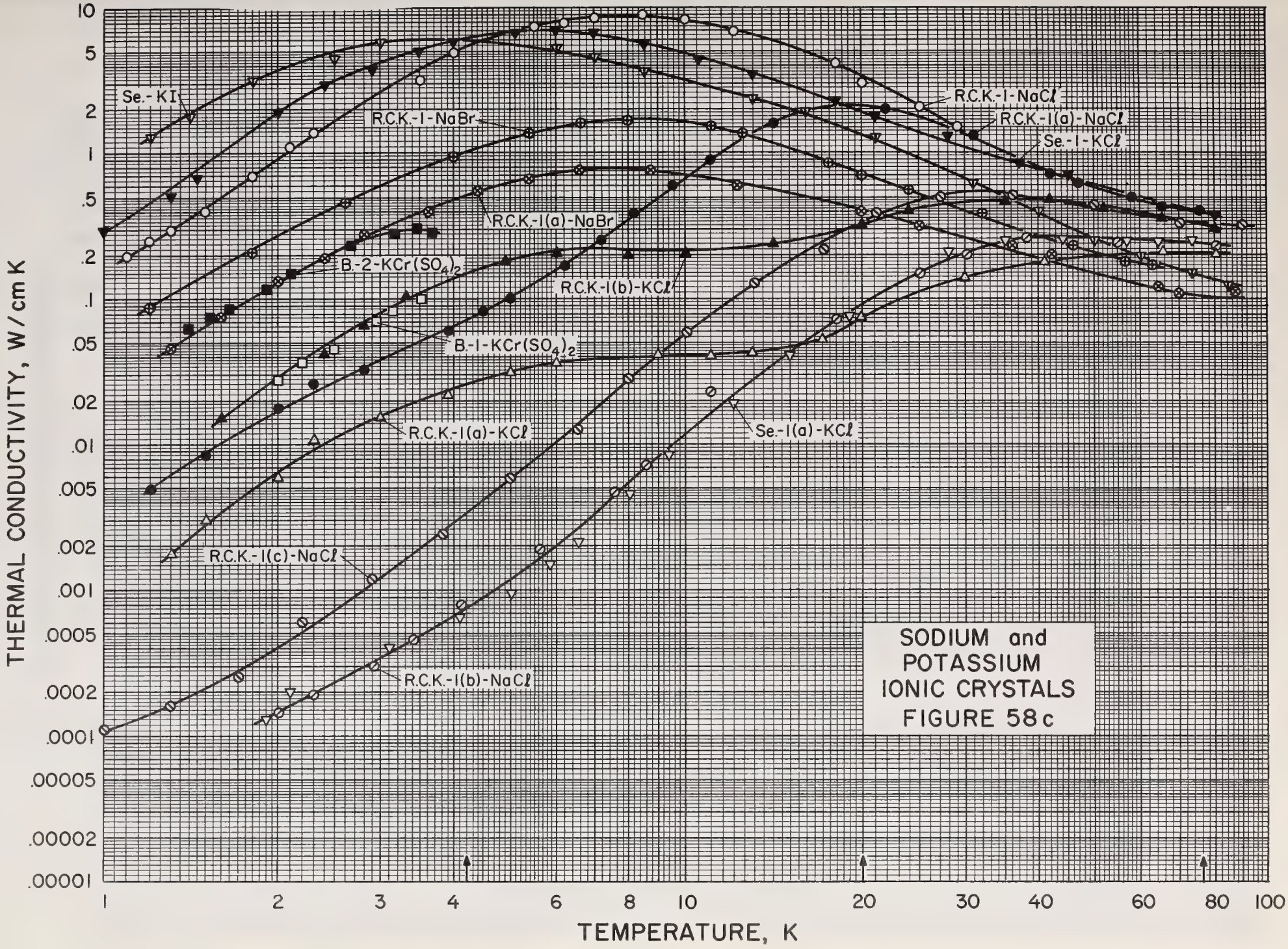
LITHIUM IONIC CRYSTALS (cont'd)

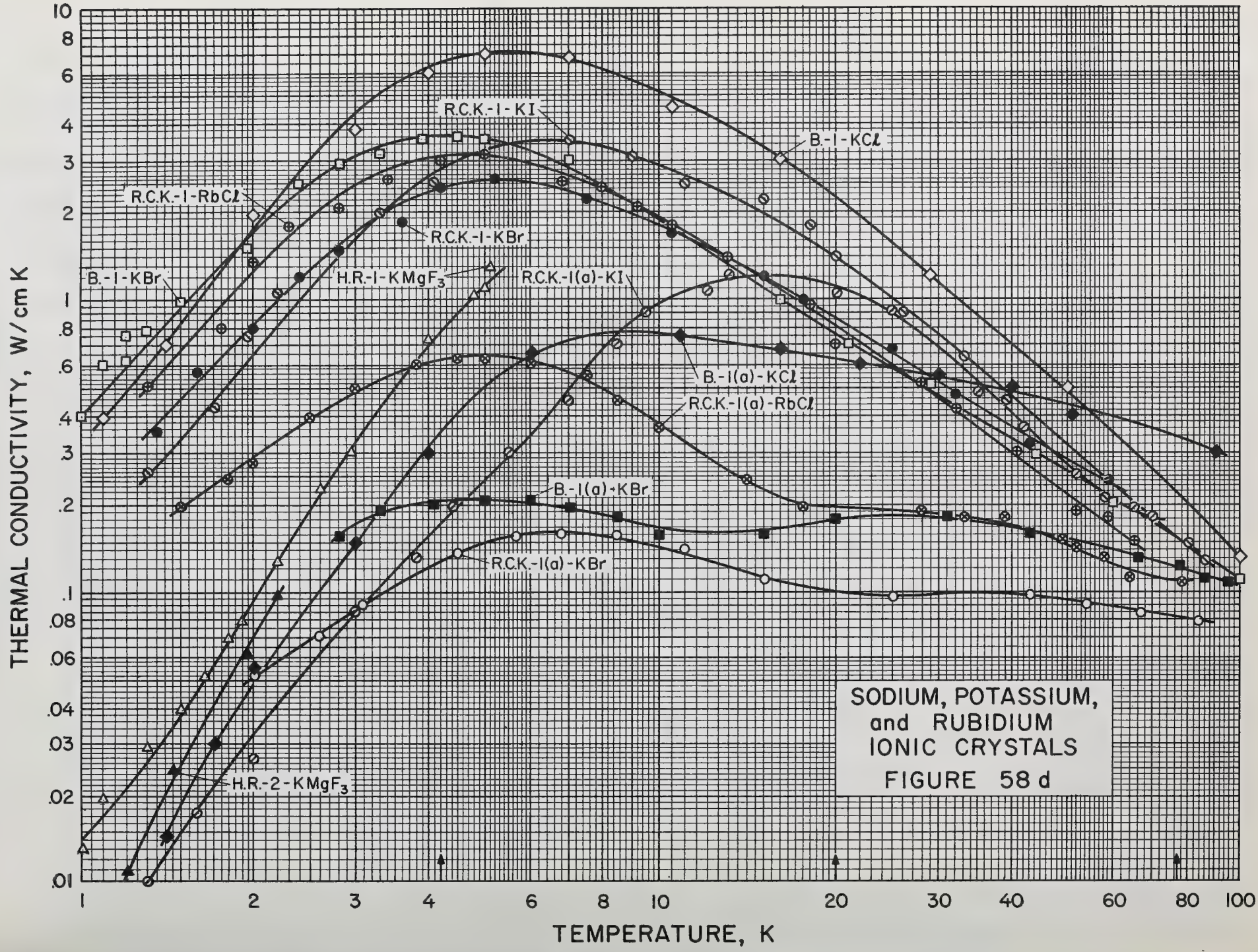
(See FIGURES 57a-57c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
S.-LiF; see also FIGURE 75	Harshaw Chemical Co; undoped.	Sandblasted. Also measured below 1 K.	A-1; B-1; C-1; D-3(2); E-5, 6; F-4; G-2; O-3; P-2, 5.	W. D. Seward (1965).
H. P. W.-1, 1(a), 1(b)-LiF	Korth; impurities of Aℓ and Cu, small amounts of Mg, Si, Ni, and Ca.	Cleaved parallel to {100} planes. #1: unannealed; also measured after annealing. #1(a): irradiated to total neutron dose of $5 \times 10^{15}/cm^2$. #1(c): irradiated to total neutron dose of $5 \times 10^{17}/cm^2$. Also measured specimens irradiated to doses of 5×10^{16} and $1 \times 10^{18}/cm^2$, with intermediate results; for $1 \times 10^{18}/cm^2$, see Lithium Semiconductor.	A-1; B-1; C-1; D-1(2); F-4; G-3; O-3; P-2, 13.	U. Himmler, H. Peisl, and W. Waidelich (1965).
T.-1(a), 1(b), 1(c), 1(d)-LiF	#1(a): Harshaw Chemical Co.; <1 ppm Aℓ, Cu, Mg, and Si; LiF of natural isotopic composition: 92.6 ^{7}Li in LiF. #1(b): ORNL; 97.2 ^{7}Li in LiF. #1(c): ORNL; 99.99 ^{7}Li in LiF. #1(d); same as #1(c).	Surfaces sandblasted; annealed before sandblasting. Mean crystal widths of: #1(a), 5.44 mm; #1(b), 5.33 mm; #1(c), 7.25 mm; #1(d), 1.06 mm. Another specimen of 50.8% ^{7}Li in LiF also measured. Also measured effect of dislocations on the thermal conductivity, with three specimens annealed to show effect of change of number of dislocations.	A-1; B-1; C-1; D-3(2); E-3, 4, 5; F-4; G-2; O-1, 3, 5; P-3, 5, 8.	P. D. Thacher (1967).
Z.-1, 2-$LiNbO_3$	$LiNbO_3$	Cut from single crystal grown from melt by Czochralski method in a constant electric field; trigonal ferroelectric. #1: rod axis parallel to trigonal axis. #2: rod axis perpendicular to trigonal axis.	A-1; B-2; C-1; D-1(4); F-4; G-3; O-3, 6, 9; S-3, 6.	V. V. Zhdanova, V. P. Klyuev, V. V. Lemanov, I. A. Smirnov, and V. V. Tikhonov (1968).
K. P.-1, 1(a)-LiF	Carl Zeiss.	Cleaved from single crystals. Annealed in air for 6 hrs at 650°C. #1: dislocation density of $2.7 \times 10^4/cm^2$; unirradiated. #1(a): specimen #1 irradiated by dose of 1.6×10^{16} neutrons/cm^2; at 140 K. Also irradiated at 310 K, with results intermediate to #1 and #1(a).	A-1; B-1; C-1; D-1(2); E-4, 8; F-4; G-3; O-3; P-2, 3.	V. G. Kvachadze and N. G. Politov (1968).


SODIUM HALIDE
IONIC CRYSTALS
FIGURE 58 a
THERMAL CONDUCTIVITY, W / cm K
TEMPERATURE, K
C.-NaF
W.-I-NaF
Wo.-I-NaCl
Wo.-I(a)-NaCl
S.Z.-I(b)-NaCl
W.-I(a)-NaF
W.-2(a)-NaF
A.B.Mc C.-I(a)-NaCl
K.(2)-I(a)-NaCl
Wo.-I(b)-NaCl
K.(2)-I-NaCl
A.B.Mc C.-I-NaCl
S.Z.-I(c)-NaCl
S.W.-I(a)-NaCl


SODIUM and
POTASSIUM CHLORIDE
IONIC CRYSTALS
FIGURE 58 b
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
S.Z.-I(a)-NaCl
K.(I)-1-NaCl
Sl.-2-KCl
B.F.Z.-KCl
K.(I)-2-NaCl
Sl.-1-KCl
P.-1-KCl
C.K.-I(a)-NaCl
Sl.-3-KCl
S.W.-I(a)-KBr
D.K.S.-1-NaCl
C.K.-I(d)-NaCl
S.W.-1-KBr
C.K.-I(b)-NaCl
K.(I)-3-NaCl
C.K.-1-NaCl
C.K.-I(c)-NaCl
P.-I(a)-KCl
McC.B.-NaCl
D.K.S.-I(a)-NaCl
20
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
4
5
6
8
10
20
30
40
50
60
80
100
200
300


THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
Se.-KI
R.C.K.-I-NaBr
R.C.K.-I-NaCl
R.C.K.-I(a)-NaCl
Se.-I-KCl
R.C.K.-I(a)-NaBr
B.-2-KCr(SO4)2
R.C.K.-I(b)-KCl
B.-I-KCr(SO4)2
R.C.K.-I(a)-KCl
Se.-I(a)-KCl
R.C.K.-I(c)-NaCl
R.C.K.-I(b)-NaCl
SODIUM and
POTASSIUM
IONIC CRYSTALS
FIGURE 58c


THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
R.C.K.-1-KI
B.-1-KCl
R.C.K.-1-RbCl
R.C.K.-1-KBr
B.-1-KBr
H.R.-1-KMgF3
R.C.K.-1(a)-KI
B.-1(a)-KCl
R.C.K.-1(a)-RbCl
B.-1(a)-KBr
R.C.K.-1(a)-KBr
H.R.-2-KMgF3
SODIUM, POTASSIUM, and RUBIDIUM IONIC CRYSTALS
FIGURE 58 d

SODIUM IONIC CRYSTALS

(See FIGURES 57c and 58a-58d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	#1: NaCℓ. #2: NaCℓ. #3: NaBr. #4: NaF. #5: 50 (mole) NaCℓ + 50 KCℓ. #6: NaCℓ. #7: NaCℓ.	#1: from a melt; k = 0.343 at 83 K; k = 0.092 at 273 K. #2: pressed at 8,000 atm; k = 0.251 at 83 K; k = 0.071 at 273 K. #3: pressed at 8,000 atm; k = 0.050 at 83 K; k = 0.025 at 273 K. #4: pressed at 8,000 atm; k = 0.059 at 83 K; k = 0.033 at 273 K. #5: pressed at 8,000 atm; k = 0.188 at 83 K; k = 0.071 at 273 K. #6: grown from solution; k = 0.378 at 83 K; k = 0.0955 at 273 K. #7: pulverized and pressed; k = 0.185 at 83 K; k = 0.0607 at 273 K.	A-1; B-1; C-1; D-1(2); F-4; G-3.	A. Eucken and G. Kuhn (1928); see also G. Kuhn (1911a).
C. -NaF	John Hopkins Applied Physic Laboratory; 0.01-0.001 Ca and Si, 0.001 Aℓ and Cu.	Cleaved surfaces.	A-1; B-1; C-1; D-3(2); G-3; O-3; P-5, 9.	A. F. Cohen (1958b).
McC. B. -NaCℓ	Harshaw Chemical Co.	. . . . .	A-6; B-2; C-1; D-1(3); F-5; G-3.	K. A. McCarthy and S. S. Ballard (1960).
K. (1)-1, 2, 3-NaCℓ	#1: grown at Cornell. #2: NaCℓ, natural rock salt from Baden, Germany. #3: Harshaw Chemical Co.; commercial synthetic.	#1: grown by Kyropoulos technique in graphite crucibles in vacuum-tight furnace; grown from material that was heated slowly in external furnace, exposed to $Cℓ_2$ for 24 hrs at 700°C, heated at 400°C in vacuum. #2 and #3: annealed in argon at least 2 hrs at 750-760°C; cooled 1°C/min to 200°C; cooled by convection to room temperature. Another specimen of NaCℓ from Optovac also measured, with results between #2 and #3. Specimens whose melts were treated with $Cℓ_2$ or doped with NaOH, Na_2O_2, or NaOD also measured; work extended by Rosenbaum, Chau, and Klein (1969) presented later.	A-1; B-1; C-1; D-3; E-4, 5; F-4; G-2; P-3, 4, 5, 9.	M. V. Klein (1961a).

SODIUM IONIC CRYSTALS (cont'd)

(See FIGURES 57c and 58a-58d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
K.(2)-1, 1(a)-NaCℓ	#1 and #1(a): originally doped with 0.014 (mole) Mn^{++}.	Grown by Kyropoulos technique in argon atmosphere in graphite crucible in vacuum-tight furnace; grown from chlorine-treated NaCℓ powder with anhydrous $MnCℓ_2$ doping; cleaved; annealed at 750°C and cooled slowly to room temperature; Mn put into solid-solution by heating for 1/2 hr at 300°C, then quartz tube plunged directly into dry ice-acetone mixture. #1: aged at room temperature for 1/2 hr; approximate fraction of Mn still in solution was 55%. #1(a): aged at room temperature for 217 hrs; approximate fraction of Mn was 3%. Another specimen of NaCℓ doped with 0.0075 mole % Mn^{++} also measured.	A-1; B-1; C-1; D-3; E-4, 5; F-4; G-2; O-3; P-2, 8, 9, 15.	M. V. Klein (1961b).
D.K.S.-1, 1(a)-NaCℓ	#1: NaCℓ. #1(a): NaCℓ + 0.031 NaBr.	Prepared same as above. Four other specimens with intermediate concentrations of NaBr also measured, with intermediate results. Specimens of NaCℓ doped with Ag, K, Li, I, and Rb also measured at room temperature, showing change in thermal resistance.	A-1; B-1; C-1; D-1(4); F-4; G-3; O-3; P-2, 9, 12; R-3.	E. D. Devyatkova, M. I. Kornfel'd, and I. A. Smirnov (1962a) and (1962b).
W.-1, 1(a), 2(a)-NaF	Harshaw Chemical Co. #1: pure NaF. #1(a): F-center concentration of 5.7×10^{16}/cm^3. #2(a): F-center concentration of 9.6×10^{16}/cm^3.	#1(a): irradiated at 35°C by x-rays for total of 24 hrs 35 min at 130 keV through Aℓ filter of 1.5 mm thickness. Irradiations for less time gave results between #1 and #1(a). #2(a): another specimen of pure NaF was irradiated at 35°C by x-rays for total of 75 hrs at 120 keV. Irradiation at less time gave results between #1(a) and #2(a).	A-1; B-1; C-1; D-1(2); E-3; F-4; G-2; O-2, 3; P-2, 5, 7, 8, 9, 14, 15.	C. T. Walker (1963).

SODIUM IONIC CRYSTALS (cont'd)

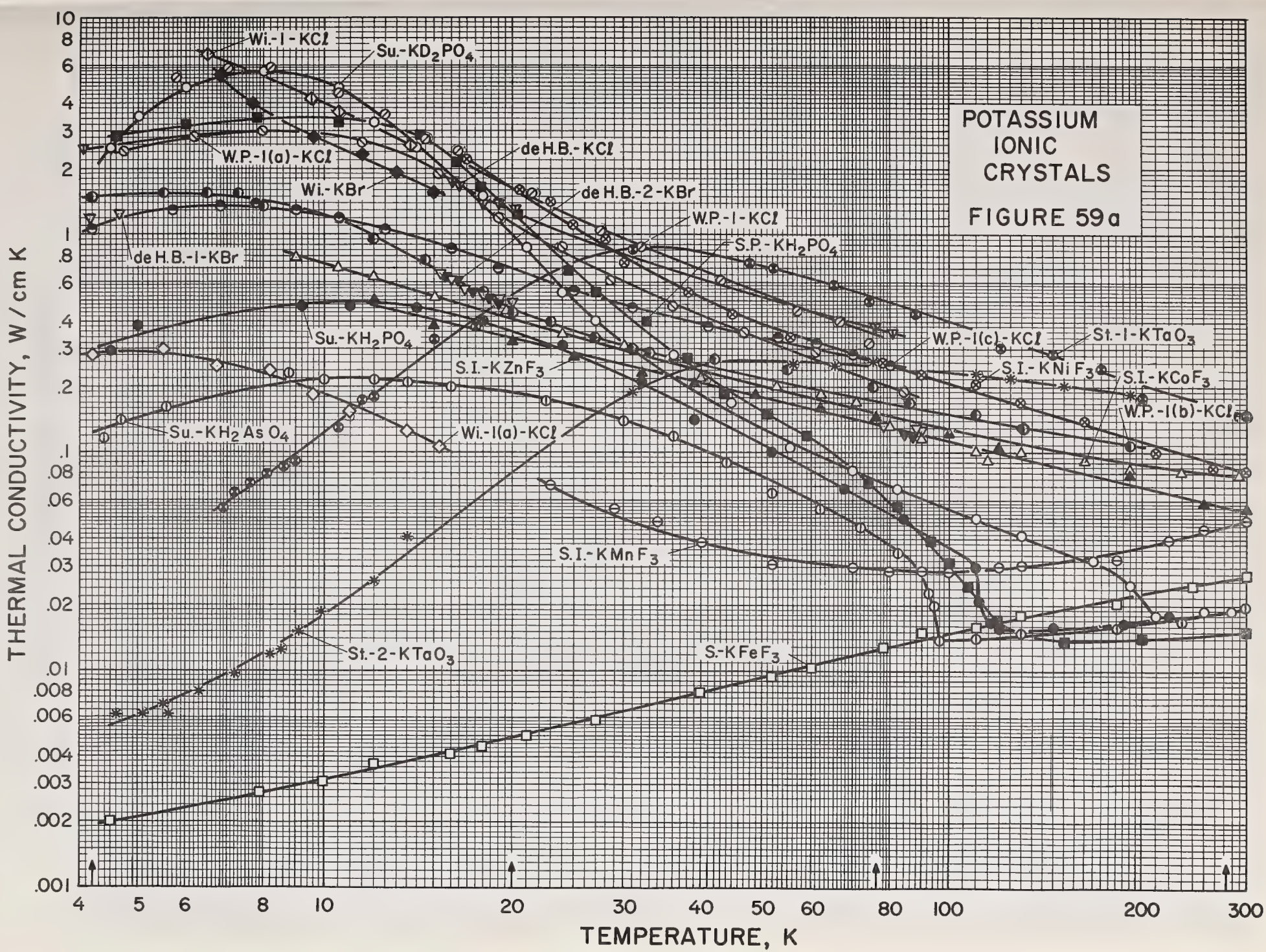
(See FIGURES 57c and 58a-58d)

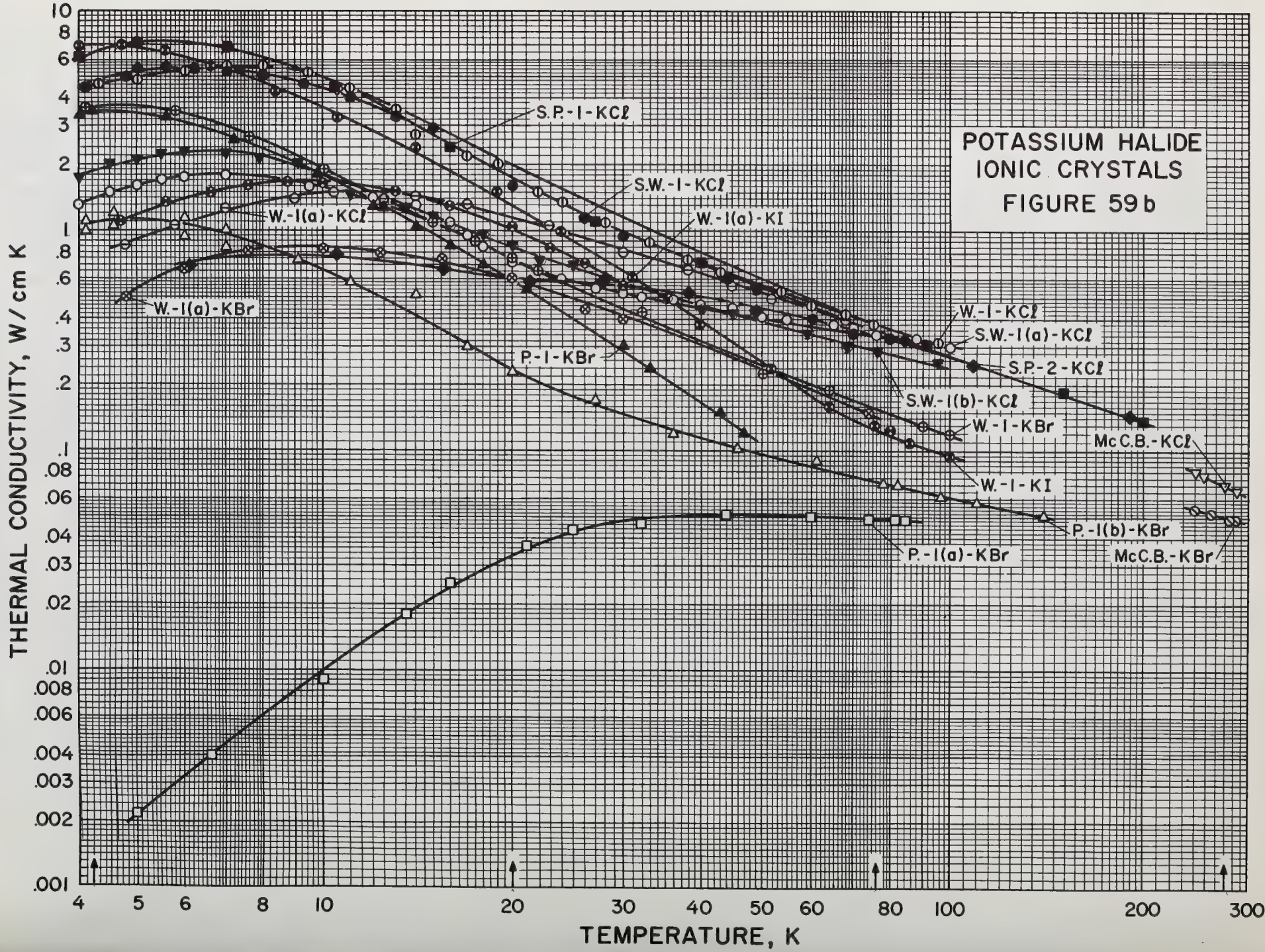
CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
Wo.-1, 1(a), 1(b)-NaCℓ	#1: "pure" NaCℓ; OH^- concentration of 7×10^{14} /cm^3 #1(a): NaCℓ + 8×10^{-4} (mole fraction) AgCℓ; range of Ag content $5 - 14 \times 10^{-4}$. #1(b): NaCℓ + 3.0×10^{-4} Ag; range of Ag content $1.8 - 5.1 \times 10^{-4}$.	#1: grown by Kyropoulos technique in argon atmosphere in alumina crucible from reagent-grade NaCℓ which had undergone several baking cycles in chlorine at 700°C. #1(a): small pellet of AgCℓ added to raw material of #1 and dissolved. Two specimens of lower Ag concentration also measured, with results between #1 and #1(a). #1(b): NaCℓ + colloidal silver; produced from mixed crystals by precipitation of silver in atmosphere of potassium vapor; held for 48 hrs at 600°C; crystals annealed in argon for 24 hrs at 600°C; cooled slowly to room temperature in 24 hrs. Three other specimens of lower colloidal silver content also measured, with results between #1 and #1(b).	A-1; B-1; C-1; D-3(2); E-2, 4; F-4; G-3; O-3; P-2, 5, 14, 15.	J. M. Worlock (1966).
. . . . .	NaCℓ.	Graphs of thermal conductivity at 300 K as a function of plastic deformation, quenching, and annealing.	. . . . .	I. A. Smirnov (1966).
S. W.-1(a)-NaCℓ	#1(a): reagent grade NaCℓ and Rocky Mountain Chemical Co. reagent-grade Sr-halide; NaCℓ: $SrCℓ_2$; 11×10^{18} Sr^{++}/cm^3; 20-40 ppm impurities.	Grown from $Cℓ_2$-treated melt by Kyropoulos technique with addition of appropriate amount of Sr-halide; cleaved in (100) directions; surfaces sanded with 400-grit paper; heated to 600°C for several hours, quenched to room temperature in 1 min. Also a specimen of pure NaCℓ and a specimen of NaCℓ: $CaCℓ_2$ measured.	A-1; B-1; C-1; D-3(2); E-4; F-4; G-3; O-2, 3; P-2, 5, 7, 8, 9, 11.	J. W. Schwartz and C. T. Walker (1967).
C. K.-1, 1(a), 1(b), 1(c), 1(d)-NaCℓ	Mallinckrodt reagent-grade NaCℓ powder. #1: pure NaCℓ. #1(a): NaCℓ + 1.4×10^{-4} CuCℓ. #1(b): NaCℓ + 3.2×10^{-2} AgCℓ. #1(c): NaCℓ + 2.1×10^{-3} NaF. #1(d): NaCℓ + 1.6×10^{-2} LiCℓ.	Starting NaCℓ material treated by passing $Cℓ_2$ gas through molten salt for 12 hrs; crystals grown by Czochralski method in argon atmosphere. Other specimens with lower concentration of substitutional impurities also measured, with results between the curves shown. Also specimens with bromine, iodine, potassium, rubidium, and thallium substitutional impurities measured.	A-1; B-1; C-1; D-3(2); E-2, 4, 5; F-4; G-3; O-2, 3; P-2, 5, 8, 9.	R. F. Caldwell and M. V. Klein (1967); see also Klein and Caldwell (1966).

SODIUM IONIC CRYSTALS (cont'd)

(See FIGURES 57c and 58a-58d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
A. B. McC. -1, 1(a)-NaCℓ	Optovac. #1(a): OH^- concentration ~ 3 ppm; F-center concentration of $7.6 \times 10^{17}/cm^3$.	Sandblasted. #1: as received. #1(a): irradiated with γ-rays; crystal has F-center concentration of $7.6 \times 10^{17}/cm^3$. Two other measurements with lower F-center concentration from γ-irradiation also measured, with intermediate results. Two other specimens with additive coloration by divalent impurities also measured.	A-6; B-2; C-1; D-1(3); F-5; G-3; O-3; P-2, 5, 7, 8, 13, 14, 15.	R. E. Aldrich, W. J. Burke, and K. A. McCarthy (1967).
See FIGURE 75	Same as Wo. -1 above.	Measured below 1.5 K; results join smoothly to Worlock data.	. . . . .	D. Walton (1967).
S. Z. -1(a), 1(b), 1(c)-NaCℓ	NaCℓ: 0.001 (weight) Ca, 0.001-0.0001 Fe, Mg, Mn, and Si, 0.0001 Aℓ.	Single crystals; cut along {100} plane. Crystals had different dislocation densities: #1(a), $5 \times 10^4/cm^2$; #1(b), $9.3 \times 10^6/cm^2$; #1(c), $5 \times 10^7/cm^2$. Two other specimens with intermediate dislocation densities also measured, with intermediate results.	A-1; B-1; C-1; D-3(2); E-1, 4; F-4; G-3; O-3; P-2, 3, 5.	E. G. Shvidkovskii and V. M. Zakharov (1967).
. . . . .	#1: NaF, pure. #2: NaF + 0.016 Cℓ.	#1: k = 0.186 at 300 K; k = 0.760 at 100 K. #2: k = 0.194 at 300 K; k = 0.760 at 100 K.	A-1; B-1; C-1; D-1(4); F-4; G-3; O-3, 9; P-2.	I. A. Smirnov (1967).
R. C. K-1, 1(a), 1(b), 1(c)-NaCℓ; see also FIGURE 75	Mallinckrodt; 4-20 ppm Ca^{++}. #1: pure NaCℓ. #1(a): NaCℓ: doped with NaOH, 4 ppm OH^-. #1(b): NaCℓ: doped with NaOH, 550 ppm OH^-. #1(c): NaCℓ: doped with NaOD, 140 ppm OD^- and OH^-.	Chlorine treated; pure crystal grown by Czochralski method. Cleaved from boule and sand-blasted. Five other specimens with intermediate concentrations of OD and/or OH also measured, with intermediate results. Also measured below 1 K.	A-1; B-1; C-1; D-3(2); E-6; G-2; O-2, 3; P-5, 7, 8.	R. L. Rosenbaum, C. -K. Chau, and M. V. Klein (1969).
R. C. K. -1, 1(a)-NaBr	#1: Harshaw; nominally pure NaBr with 8 ppm OH^-. #1(a): NaBr: NaOH, doped with NaOH; 64 ppm OH^-.	. . . . .	Same as above.	Same as above.


POTASSIUM
IONIC
CRYSTALS
FIGURE 59a
THERMAL CONDUCTIVITY, W / cm K
TEMPERATURE, K
Wi.-I-KCl
Su.-KD2PO4
W.P.-I(a)-KCl
deH.B.-KCl
Wi.-KBr
deH.B.-2-KBr
W.P.-I-KCl
S.P.-KH2PO4
deH.B.-I-KBr
Su.-KH2PO4
W.P.-I(c)-KCl
St.-I-KTaO3
S.I.-KNiF3
S.I.-KCoF3
S.I.-KZnF3
W.P.-I(b)-KCl
Su.-KH2AsO4
Wi.-I(a)-KCl
S.I.-KMnF3
St.-2-KTaO3
S.-KFeF3


POTASSIUM HALIDE
IONIC CRYSTALS
FIGURE 59b
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
S.P.-1-KCl
S.W.-1-KCl
W.-1(a)-KCl
W.-1(a)-KI
W.-1(a)-KBr
P.-1-KBr
W.-1-KCl
S.W.-1(a)-KCl
S.P.-2-KCl
S.W.-1(b)-KCl
W.-1-KBr
McC.B.-KCl
W.-1-KI
P.-1(b)-KBr
McC.B.-KBr
P.-1(a)-KBr
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
.01
.008
.006
.004
.003
.002
.001
4
5
6
8
10
20
30
40
50
60
80
100
200
300

POTASSIUM IONIC CRYSTALS

(See FIGURES 57c, 58b-d, and 59a-59b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	#1: KCℓ. #2: KCℓ. #3: KCℓ. #4: KCℓ. #5: KCℓ. #6: KBr. #7: KI. #8: KF. #9: 90(mole)KBr-10 KCℓ. #10: 75 KBr-25 KCℓ. #11: 50 KBr-50 KCℓ. #12: 75 KCℓ-25 KBr. #13: 90 KCℓ-10 KBr. #14: 50 KCℓ-50 NaCℓ. #15: KNO_3. #16: $K_4(FeCN_6)$. #17: potassium alum. #18: potassium bichromate. #19: potassium bichromate.	#1: pressed at 8,000 atm; k = 0.314 at 83 K; k = 0.088 at 273 K. #2: prepared from a melt; k = 0.402 at 83 K; k = 0.092 at 273 K. #3: pressed at 1,250 atm; k = 0.243 at 83 K; k = 0.075 at 273 K. #4: pressed to 2,500 atm; k = 0.368 at 83 K; k = 0.092 at 273 K. #5: pressed at 8,900 atm; k = 0.402 at 83 K; k = 0.096 at 273 K. #6: pressed at 8,000 atm; k = 0.092 at 83 K; k = 0.038 at 273 K. #7: pressed at 8,000 atm; k = 0.121 at 83 K; k = 0.029 at 273 K. #8: pressed at 8,000 atm; k = 0.234 at 83 K; k = 0.071 at 273 K. #9: pressed at 8,000 atm; k = 0.050 at 83 K; k = 0.029 at 273 K. #10: pressed at 8,000 atm; k = 0.029 at 83 K; k = 0.021 at 273 K. #11: pressed at 8,000 atm; k = 0.025 at 83 K; k = 0.025 at 273 K. #12: pressed at 8,000 atm; k = 0.046 at 83 K; k = 0.033 at 273 K. #13: pressed at 8,000 atm; k = 0.080 at 83 K; k = 0.050 at 273 K. #14: pressed at 8,000 atm; k = 0.188 at 83 K; k = 0.071 at 273 K. #15: pressed at 8,000 atm; k = 0.017 at 83 K; k = 0.021 at 273 K. #16: k = 0.017 at 83 K and 273 K. #17: k = 0.013 at 83 K; k = 0.021 at 273 K. #18: rod axis perpendicular to main crystal axis; k = 0.017 at 83 K; k = 0.021 at 273 K. #19: rod axis parallel to main crystal axis; k = 0.017 at 83 K and 273 K.	A-1; B-1; C-1; D-1(2); F-4; G-3.	A. Eucken and G. Kuhn (1928).
deH. B.-1, 2-KBr	~0.03 Na, <0.01 Mg.	#1: specimen had amalgam contacts for thermometry. #2: same specimen had soldered contacts.	A-1; B-1; C-1; D-2(2); E-2, 5; F-4; G-3; O-3; P-5.	W. J. deHaas and T. Biermasz (1937).
deH. B.-KCℓ	<0.01 Mg and Na.	. . . . .	Same as above.	Same as above.

POTASSIUM IONIC CRYSTALS (cont'd)

(See FIGURES 57c, 58b-d, and 59a-59b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	Measured the change in thermal conductivity with the change in crystal cross-section for four specimens; the thermal conductivity was decreased by 1/3 at 2 K for change in diameter of rod from 0.511 to 0.252 cm.	. . . . .	W. J. deHaas and T. Biermasz (1938a).
B. -1, 2- $KCr(SO_4)_2$	$KCr(SO_4)_2 \cdot 12\ H_2O$; 10.46 Cr, 0.007 Fe.	Chromium potassium alum; turbid spots and small bubbles. #1: cooled as quickly as possible. #2: cooled slowly.	A-1; B-1; C-1; D-6(2); F-4; G-3; P-1.	D. Bijl (1949).
See FIGURE 75	Potassium chromium alum.	Measured below 1 K.	. . . . .	C. G. B. Garrett (1950).
B. F. Z. -KCℓ	Harshaw Chemical Co.; <0.01 Aℓ and Mg, smaller concentrations of Fe, Mn, Na, and Si.	. . . . .	A-1; B-1; C-1; D-3, 4(2); E-4; F-4; G-2; O-3; P-2, 8.	R. Berman, E. L. Foster, and J. M. Ziman (1956).
. . . . .	#1: KCℓ. #2: KBr.	#1: k = 0.093 at 113 K; k = 0.035 at 250 K. #2: k = 0.209 at 89 K; k = 0.0209 at 300 K.	A-1; B-1; C-1; D-1(2); F-4; G-3; O-3; P-2, 12; R-4.	A. F. Joffe (1956).
Sℓ. -1, 2, 3- KCℓ	Harshaw Chemical Co., starting material KCℓ. No heavy metals, Na, Be, or Mg not detected; <10 ppm Sr, <5 ppm Ca and Ba, 20 ppm Br, <20 ppm I, <1 ppm graphite. #1: Harshaw. #2: doped with CaCℓ; ratio of Ca atoms/cm^3 to no. of K atoms/cm^3 was 0.6×10^{-4}. #3: doped with CaCℓ; ratio of Ca atoms/cm^3 to no. of K atoms/cm^3 was 2.1×10^{-4}.	#1: single crystal; annealed. #2: starting material split, melted, crystal grown by modified Kyropoulos technique in graphite mold at rate of 1.4 cm/hr; cleaved; two faces ground; annealed in air for 1/2 hr at 700°C; cooled to room temperature at 30°/hr; 4×10^4 dislocations/cm^2. #3: same as #2, but no faces were ground; 5×10^4 dislocations/cm^2. Three other specimens also measured, with intermediate results.	A-1; B-1; C-1; D-3(2); E-4; F-4; G-3; O-2, 3; P-2, 3, 4, 5, 8, 11, 15.	G. A. Slack (1957b); see also Slack (1957a).

POTASSIUM IONIC CRYSTALS (cont'd)

(See FIGURES 57c, 58b-d, and 59a-59b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	KCℓ.	Cleaved surfaces; maximum thermal conductivity of 8.2 W/cm-K at 6.2 K. Following annealing, increased thermal conductivity was observed. Irradiation by Co^{60} γ-rays at room temperature on unannealed specimen increased the thermal conductivity.	. . . . .	A. F. Cohen (1958a).
Wi.-1, 1(a)-KCℓ	#1: Harshaw Chemical Co.; pure. #1(a): Harshaw Chemical Co.; optical grade KCℓ and KBr; KCℓ-47.8(mole) KBr.	Single crystals. #1: pure. #1(a): prepared by pulling from the melt in high-purity graphite crucibles at rate of 1.3 cm/hr, rotated during growth, in 92% N_2 + 8% H_2 atmosphere; pulled into hot zone; annealed for 1-1/2 hrs to 75°C below melt point; cooled to room temperature over 15 hr period; cleaved; annealed again in same fashion. Three other mixed-crystal specimens with intermediate compositions also measured, with intermediate results.	A-1; B-2; C-1; D-1(2); E-4, 8; F-4; G-3; P-2, 8, 12, 15.	W. S. Williams (1960).
Wi.-KBr	Harshaw Chemical Co., pure.	Single crystal. Grown same as Wi.-1(a)-KCℓ.	Same as above.	Same as above.
McC. B-KCℓ, KBr	Harshaw Chemical Co.	. . . . .	A-6; B-2; C-1; D-1(3); F-5; G-3.	K. A. McCarthy and S. S. Ballard (1960).
P.-1, 1(a)-KCℓ	#1: pure reagent-grade KCℓ. #1(a): KCℓ, doped with KNO_2; KNO_2 concentration of $4 \times 10^{18}/cm^3$.	Single crystals. Grown in $Aℓ_2O_3$ sintered crucibles, Cℓ treated; grown in Ar atmosphere. Four other specimens with intermediate concentrations of KNO_2 also measured, with intermediate results.	A-1; B-2; C-1; D-1(2); E-4, 8; F-4; G-3; O-3; P-2, 7.	R. O. Pohl (1962); see also Pohl (1960).
W. P.-1, 1(a), 1(b), 1(c)-KCℓ	Reagent grade material. #1: KCℓ, pure. #1(a): KCℓ, doped with NaCℓ; Na^+ concentration of $2.3 \times 10^{19}/cm^3$. #1(b): KCℓ, doped with KI; I^- concentration of $5.0 \times 10^{19}/cm^3$. #1(c): KCℓ, doped with $CaCℓ_2$; Ca^{++} concentration of $4.7 \times 10^{18}/cm^3$.	Grown by Kyropoulos technique using $Cℓ_2$-treated materials, grown in argon atmosphere in sintered alumina crucibles; cleaved in [100] directions; sandblasted. #1(c): annealed 2 hrs at 400°C; quickly quenched to room temperature in 2-3 min, immediately mounted and cooled. Specimens of lower dopant concentrations also measured, with intermediate results. Also measured 2 other specimens to determine effect of quenching.	A-1; B-1; C-1; D-1, 3(2); E-4, 5; F-4; G-3; O-2, 3, 9; P-2, 4, 5, 7, 8, 9, 15.	C. T. Walker and R. O. Pohl (1963).

POTASSIUM IONIC CRYSTALS (cont'd)

(See FIGURES 57c, 58b-d, and 59a-59b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
W.-1, 1(a)-KCℓ	#1: pure KCℓ. #1(a): F-center concentration of $7.0 \times 10^{17}/cm^3$.	Grown same as above. Application of F-centers by irradiation. #1(a): total irradiation by x-rays through 1.5 mm aluminum filter at 70 keV of 26 hrs 48 min, and γ-irradiation of 10^8 R from Co^{60} source. Measurements after shorter lengths of x-ray irradiations with lower F-center concentration had intermediate results. Also measured KCℓ specimens after additive colorations.	A-1; B-1; C-1; D-1(2); E-1, 2; F-4; G-3; O-2, 3; P-2, 5, 7, 8, 9, 14, 15.	C. T. Walker (1963).
W.-1, 1(a)-KBr	#1: pure KBr. #1(a): F-center concentration of $4.7 \times 10^{17}/cm^3$.	Grown same as above. Application of F-centers by irradiation. #1(a): total irradiation by γ-rays from Co^{60} source of 144 hrs at rate of 2×10^6 R/hr. Measurement at 22 hrs of irradiation with lower F-center concentration had intermediate results.	Same as above.	Same as above.
W.-1, 1(a)-KI	Harshaw. #1: pure KI. #1(a): F-center concentration of $4.0 \times 10^{17}/cm^3$.	Application of F-centers by irradiation as discussed above. #1(a): same as W.-1(a)-KBr above. Measurement at 22 hrs of irradiation with lower F-center concentration had intermediate results.	Same as above.	Same as above.
P.-1, 1(a), 1(b)-KBr	Harshaw Chemical Co. KBr, reagent grade. #1: pure KBr. #1(a): KBr + 1.0(mole) KNO_2 added to melt; NO_2 concentration of $5.7 \times 10^{19}/cm^3$; NO_3 concentration of $1.1 \times 10^{19}/cm^3$. #1(b): KBr + 2.0 KI added to melt; defect concentration of $\sim 16 \times 10^{19}/cm^3$.	Single crystals; grown by Kyropoulos technique in sintered $Aℓ_2O_3$ crucibles from Br_2-treated KBr in argon atmosphere, with KNO_2 or KI added to the melt; cleaved from top of boule; sandblasted. Other specimens with intermediate concentrations also measured, with intermediate results.	A-1; B-1; C-1; D-1(2); E-4, 8; F-4; G-2; P-2, 5, 7, 8.	R. O. Pohl (1963).
S. P.-1, 2-KCℓ	#1: pure. #2: KCℓ-1.0(mole) Li, Cℓ, in melt.	#2: concentration of Li^+ in the crystal is probably less than that in the melt.	A-1; B-1; C-1; D-1(2); E-4, 8; F-4; G-3; O-3; P-2, 5, 7, 12.	A. J. Sievers and R. O. Pohl (1964).
S. P.-KH_2PO_4	. . . . .	Ferroelectric-paraelectric transition at 116 K.	Same as above.	Same as above.

POTASSIUM IONIC CRYSTALS (cont'd)

(See FIGURES 57c, 58b-d, and 59a-59b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
S. I. -$KMnF_3$, $KCoF_3$, $KNiF_3$, $KZnF_3$	$KMnF_3$: impurity concentrations of $1.10 \times 10^{18}/cm^3$ Fe, $3.5 \times 10^{17}/cm^3$ Co and Ni. $KCoF_3$: impurity concentrations of $3.89 \times 10^{19}/cm^3$ Mn, $1.70 \times 10^{18}/cm^3$ Fe; $3.9 \times 10^{17}/cm^3$ Ni. $KNiF_3$: impurity concentration of $8.33 \times 10^{18}/cm^3$ Mn, $2.00 \times 10^{18}/cm^3$ Fe, $7.4 \times 10^{17}/cm^3$ Co. $KZnF_3$: $6.8 \times 10^{19}/cm^3$ Cℓ, $4.4 \times 10^{17}/cm^3$ Mn, $4.1 \times 10^{17}/cm^3$ Co, Fe, and Ni.	Single crystals; prepared by flux method; mixed anhydrous chloride of divalent iron group and potassium hydrogen difluoride in platinum crucibles, heated to 900°C in argon and hydrogen fluoride gases; cooled at 20°C/hr to 500°C, then cooled rapidly to room temperature; ground along (100) direction. $KZnF_3$: prepared by flux-melt method; crystallites heat to 1000°C in carbon crucible for 4 hrs in argon gas; cooled to 500°C at 10°C/hr, and cooled to room temperature at 20°C/hr; rod axis parallel to (100) direction. $KMnF_3$ was pink; $KCoF_3$ was dark red; $KNiF_3$ was yellow-green; $KZnF_3$ colorless. $KMnF_3$: on cooling, changes from cubic to tetragonal ($c/a > 1$) at 184 K, to tetragonal ($c/a < 1$) at 88 K. $KCoF_3$: on cooling, changes from cubic to tetragonal ($c/a < 1$) at 114 K.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-2; O-3; P-2, 8; Q-5.	Y. Suemune and H. Ikawa (1964).
S. -$KFeF_3$	. . . . .	Single crystal; prepared by flux growth method; KHF_2, $FeCl_2$, and FeF_3 in molar ratio 3.1: 1.0:0.1 heated in carbon crucible to 900°C in argon; cooled slowly; cut and ground along (100) directions; dark, yellowish-brown transparent. On cooling, changes from perovskite cubic to rhombohedral at 113 K.	A-1; B-1; C-1; D-1(2); E-5; F-4; G-2; P-7; Q-5.	Y. Suemune (1964).
. . . . .	. . . . .	Graph of effective change in thermal conductivity of $KMgF_3$ crystals doped with Ni^2 and Co^2 between 1 and 4.2 K due to magnetic fields up to 5.2 T.	. . . . .	P. V. E. McClintock and H. M. Rosenberg (1965).
Se. -1, 1(a)-KCℓ; also see FIGURE 75	#1: KCℓ, high purity. #1(a): KCℓ doped with CN^-, concentration of $4.9 \times 10^{19}/cm^3$.	Sandblasted. Two other specimens of intermediate composition also measured, with intermediate results. Also measured below 1 K.	A-1; B-1; C-1; D-3(2); E-5, 6; F-4; G-2; O-3; P-2, 5, 7.	W. D. Seward (1965).
Se. -KI	High purity.	Sandblasted.	Same, except no P-7.	Same as above.

POTASSIUM IONIC CRYSTALS (cont'd)

(See FIGURES 57c, 58b-d, and 59a-59b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
S.W.-1, 1(a), 1(b)-KCl	#1: pure KCl. #1(a): KCl, doped with 200-300 ppm $BaCl_2$. #1(b): KCl, doped with 200-300 ppm $CaCl_2$.	Specimens of KCl doped with Eu and Sr also measured, with results between #1(a) and #1(b).	A-1; B-1; C-1; D-3(2); E-4; F-4; G-3; P-7, 11, 15.	J.W. Schwartz and C.T. Walker (1966).
Su.-KH_2PO_4, KD_2PO_4, KH_2AsO_4	. . . . .	Single crystals; paraelectric materials; tetragonal at room temperature; rod axis parallel to c-axis. Specimens also measured with rod axis parallel to a-axis.	A-1; B-1; C-1; D-1(2); E-1, 4; F-4; G-3; O-3, 6; P-7, 8.	Y. Suemune (1966b).
S.W.-1, 1(a)-KBr	#1: pure KBr; from reagent-grade material; impurities of ~20-40 ppm. #1(a): Rocky Mountain Chemical Co. reagent-grade $BaBr_2$; KCl + $BaBr_2$; ~100-500 ppm impurity.	#1: grown from melt by Kyropoulos technique by HBr-treated melt, grown in high-purity graphite crucibles; cleaved in (100) directions; sanded. #1(a): doped KBr, grown by adding appropriate amount to melt before HBr-treatment; cleaved and surfaces sanded. Both #1 and #1(a) heated to 600°C for several hours and quenched quickly in 1 min to room temperature. Also specimen of KBr: $SrBr_2$ measured, with intermediate responses.	A-1; B-1; C-1; D-3(2); E-4; F-4; G-3.	J.W. Schwartz and C.T. Walker (1967).
B.-1, 1(a)-KCl	Reagent-grade material. #1: pure KCl. #1(a): KCl doped with Li, Li concentration of $4.8 \times 10^{18}/cm^3$.	Prepared by seed-pulling under halogen atmosphere; no NO_2^-, CN^-, or OH^- observed; cleaved along {100} planes; sandblasted. Two other specimens with intermediate concentration also measured, with intermediate results. Two other specimens measured to study Li^+ isotope effect. Relative change in thermal conductivity due to electric field of 6 kV/cm along (100) direction perpendicular to rod axis also measured. Also measured below 1 K.	A-1; B-1; C-1; D-1(2); E-4, 8; F-4; G-3; O-3, 9; P-2, 5, 7, 8.	F.C. Baumann, J.P. Harrison, R.O. Pohl, and W.D. Seward (1967).
B.-1, 1(a)-KBr; also see FIGURE 75	Reagent-grade material. #1: pure KBr. #1(a): KBr doped with Li, Li concentration of $1.8 \times 10^{19}/cm^3$.	Same as above.	Same as above.	Same as above.

POTASSIUM IONIC CRYSTALS (cont'd)

(See FIGURES 57c, 58b-d, and 59a-59b)

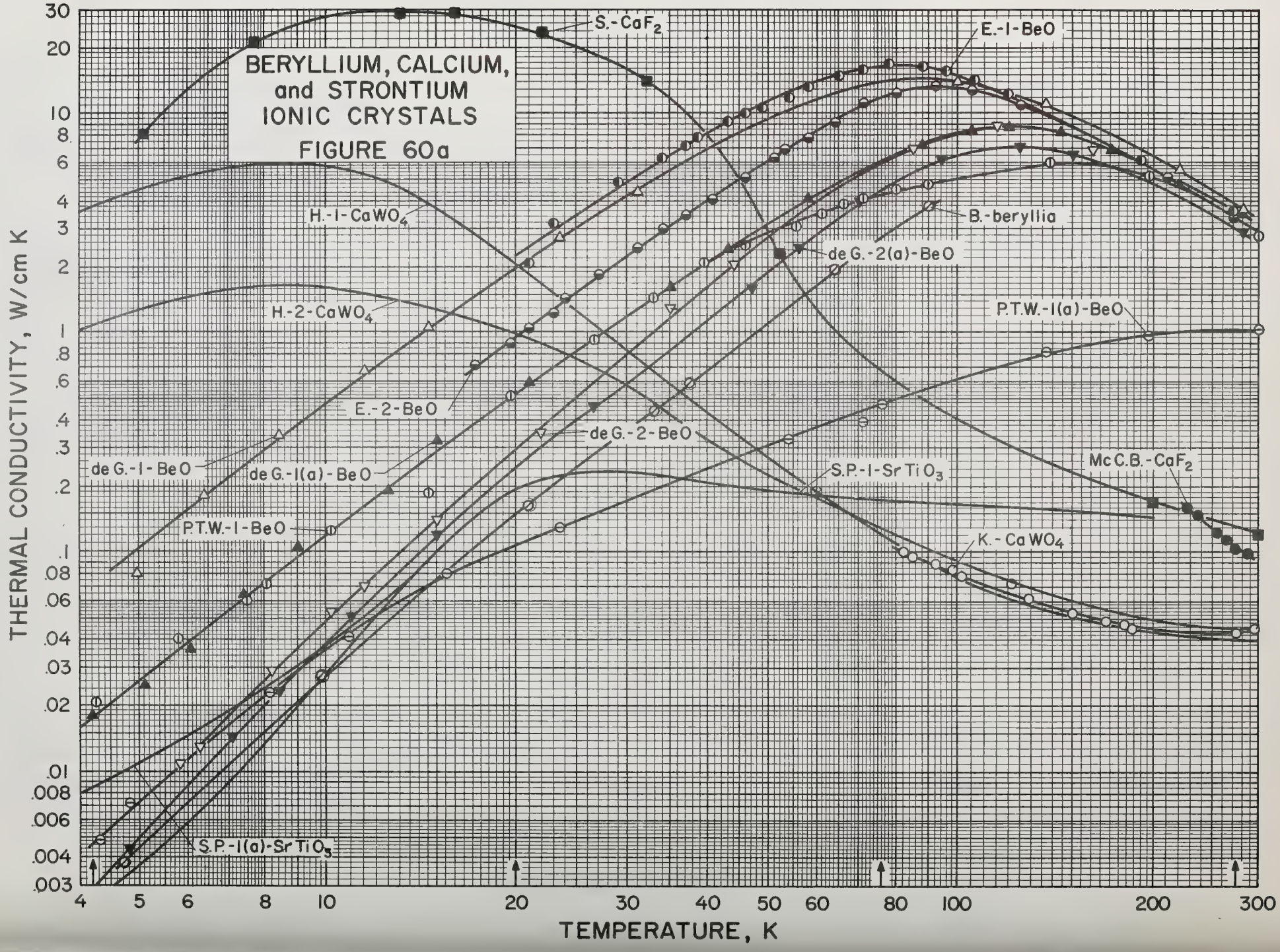
CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
R.C.K-1(a), 1(b)-KCℓ	#1(a): KCℓ, doped with KOH, 1520 ppm OH^-. #1(b): KCℓ, doped with KOH 235 ppm OD^-.	Specimen of pure KCℓ and of KCℓ:KOH or KCℓ:KOD with lower concentrations also measured; pure specimen had values nearly identical to Se.-1-KCℓ. Also measured below 1 K.	A-1; B-1; C-1; D-3(2); E-6; G-2; O-2, 3; P-5, 7, 8.	R.L. Rosenbaum, C.-K. Chau, and M.V. Klein (1969); see also Chau, Klein, and B. Wedding (1966).
R.C.K.-1, 1(a)-KI; also see FIGURE 75	#1: Cornell; pure KI. #1(a): KI, doped with KOH, 90 ppm OH^-.	Another specimen of pure KI also measured, with intermediate results. Also measured below 1 K.	Same as above.	Same as above.
R.C.K.-1, 1(a)-KBr	#1: pure KBr. #1(a): KBr, doped with KOH, 1530 ppm OH^-.	Another specimen of KBr: 950 ppm OD^- also measured, with intermediate results. Also measured below 1 K.	Same as above.	Same as above.
St.-1, 2-$KTaO_3$	RCA. #1: < 300 ppm Na and Nb, < 100 ppm Li, < 60 ppm Mg, < 30 ppm Ba and Ca, < 10 ppm Cu and Fe.	All faces {100} oriented. #1: clear and transparent. #2: translucent. Also measured in an electric field of up to 55 kV/cm, but there was negligible change.	A-1; B-1; C-1; D-1(2); E-3, 4; F-4; G-3; O-9; P-5, 7, 8.	E.F. Steigmeier (1968).
H.R.-1, 2-$KMgF_3$; also see FIGURE 75	British Drug Houses; doped with Ni^{2+}. #1: 0.5(atomic) Ni. #2: 3.0 Ni.	Single crystals; grown from melt using zone-refined KF and MgF_2 and NiF_2; annealed 18-24 hrs at 1230 K in He, cooled slowly for 30 hrs; rod axis parallel to ⟨100⟩ axis. Also measured in a longitudinal magnetic field of up to 5 T. Also measured below 1 K.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-3; O-5, 9; P-2, 5, 7, 10.	R.T. Harley and H.M. Rosenberg (1970).

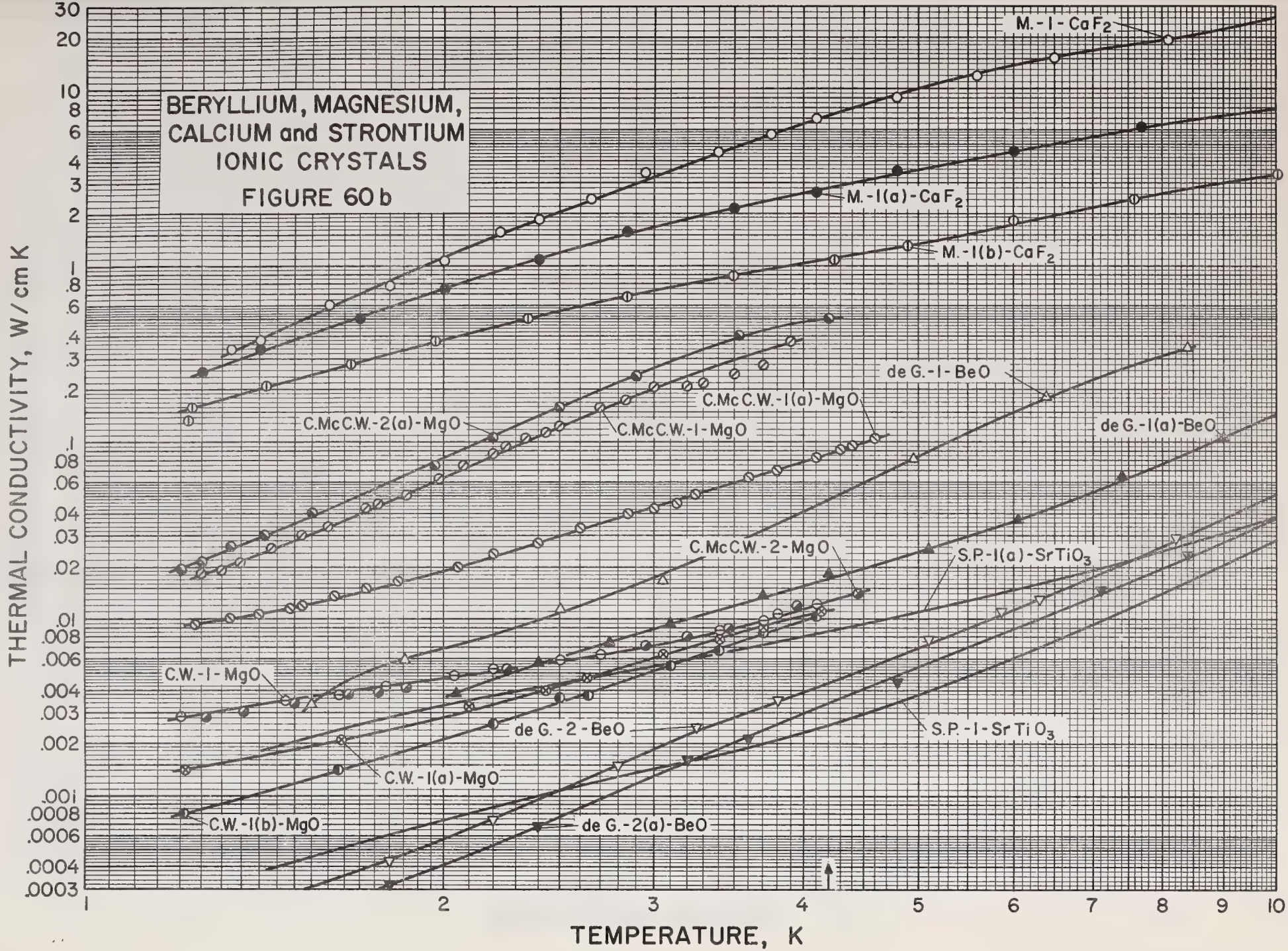
RUBIDIUM IONIC CRYSTALS
(See FIGURE 58d)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	#1: RbI. #2: RbCℓ.	#1: pressed at 8,000 atm; k = 0.059 at 83 K; k = 0.033 at 273 K. #2: pressed at 8,000 atm; k = 0.029 at 83 K; k = 0.021 at 273 K.	A-1; B-1; C-1; D-1(2); F-4; G-3.	A. Eucken and G. Kuhn (1928).
R.C.K.-1, 1(a)-RbCℓ; also see FIGURE 75	#1: pure RbCℓ. #1(a): RbCℓ, doped with RbOH, 480 ppm OH.	Also measured below 1 K.	A-1; B-1; C-1; D-3(2); E-6; G-2; O-2, 3; P-5, 7, 8.	R. L. Rosenbaum, C.-K. Chau, and M. V. Klein (1969

CESIUM IONIC CRYSTALS

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Harshaw Chemical Co. #1: CsI. #2: CsBr.	#1: k = 0.014 at 227 K; k = 0.013 at 243 K; k = 0.0125 at 265 K; k = 0.0119 at 277 K; k = 0.011 at 295 K. #2: k = 0.012 at 228 K; k = 0.01 at 249 K; k = 0.0095 at 269 K; k = 0.009 at 294 K.	A-6; B-2; C-1; D-1(3); F-5; G-3.	K. A. McCarthy and S. S. Ballard (1960).

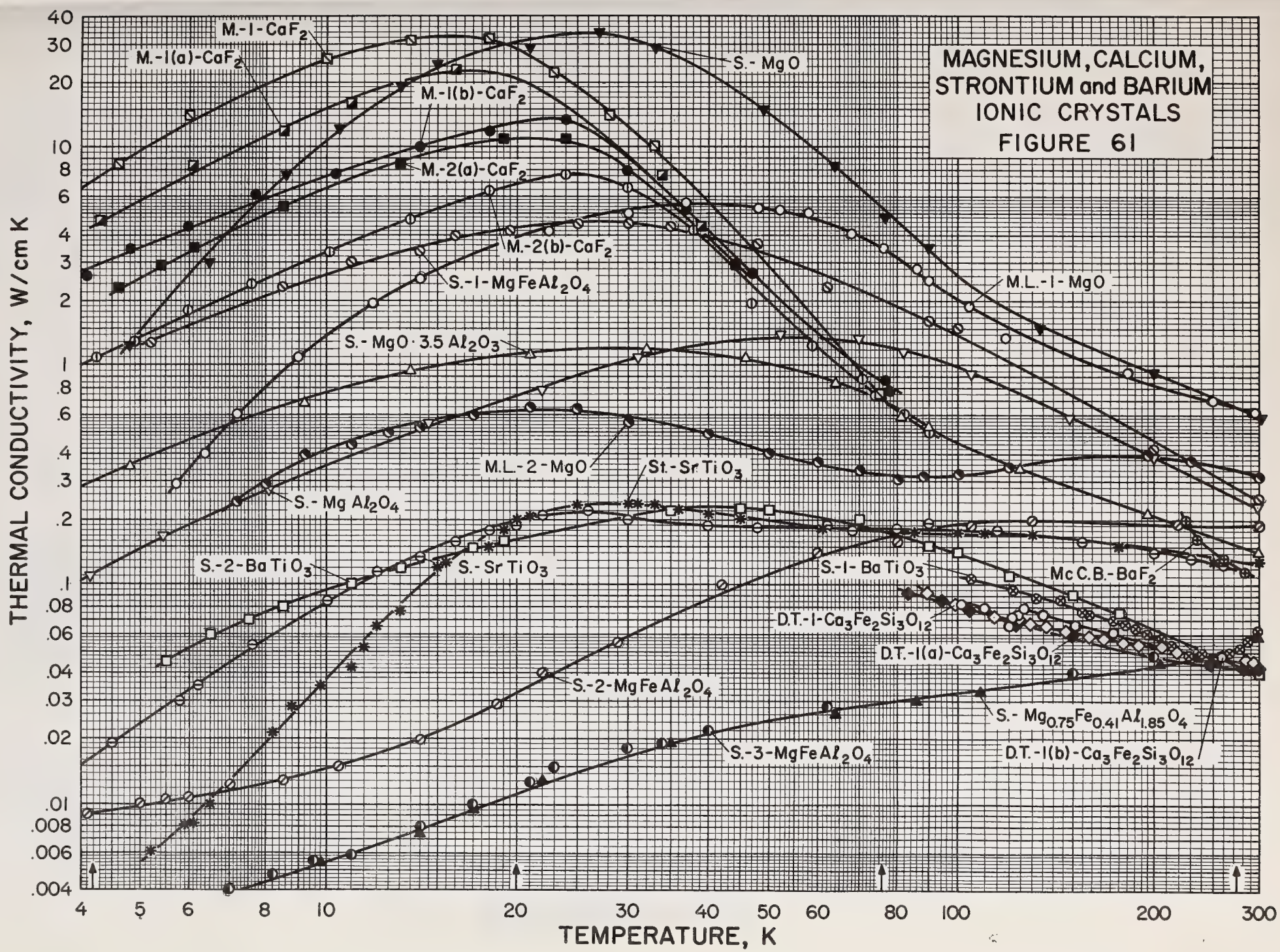

BERYLLIUM, CALCIUM, and STRONTIUM IONIC CRYSTALS
FIGURE 60a
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
S.-CaF2
E.-1-BeO
H.-1-CaWO4
B.-beryllia
deG.-2(a)-BeO
H.-2-CaWO4
P.T.W.-1(a)-BeO
E.-2-BeO
deG.-2-BeO
deG.-1-BeO
deG.-1(a)-BeO
S.P.-1-SrTiO3
McC.B.-CaF2
P.T.W.-1-BeO
K.-CaWO4
S.P.-1(a)-SrTiO3


BERYLLIUM, MAGNESIUM, CALCIUM and STRONTIUM IONIC CRYSTALS
FIGURE 60 b
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
M.-I-CaF2
M.-I(a)-CaF2
M.-I(b)-CaF2
de G.-I-BeO
de G.-I(a)-BeO
C.McC.W.-I(a)-MgO
C.McC.W.-2(a)-MgO
C.McC.W.-I-MgO
C.McC.W.-2-MgO
S.P.-I(a)-SrTiO3
C.W.-I-MgO
de G.-2-BeO
S.P.-I-SrTiO3
C.W.-I(a)-MgO
C.W.-I(b)-MgO
de G.-2(a)-BeO

BERYLLIUM IONIC CRYSTALS

(See FIGURES 60a and 60b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
B. -beryllia	Atomic Energy Research Estab.	Sintered; density of 2.94 g/cm^3 (97% of single crystal); crystallites 10-40μ.	A-1; B-1; C-1; D-3, 4(2); E-4; F-4; G-3; O-3, 5; P-4, 5.	R. Berman (1952a).
E. -1, 2-BeO	Metallic impurities, 0.05, mainly Fe. #2: doped with 0.6 CaO.	Grain size of 6-60μ. #1: density of 2.93 g/cm^3; correction factor of 3% included. #2: density of 2.79 g/cm^3; correction factor of 7% included. Another specimen also measured, with intermediate results.	A-1; B-1; C-1; D-1(2); G-3; O-3; P-2, 4.	J. Elston, J. de Goer, and Z. Mihailovic (1964).
P. T. W. -1, 1(a)-BeO	Australian Atomic Energy Commission; prepared with Brush Beryllium Corp. "UOX" powder; 800 ppm C, 250 ppm Fe, 100 ppm Cu + Ni + Cr + Mg + Na, 50 ppm Aℓ and Ca, 40 ppm Si.	#1: cold-pressed and sintered 1-3/2 hrs at 1750°C in air. Grain size 25-45μ, unirradiated; density of 0.98 of theoretical. #1(a): irradiated at 75°C with fast neutrons at dose of 1 x 10^{20} nvt. Two other unirradiated specimens with intermediate crystal size also measured. Two other specimens were irradiated, one with 1 MeV γ-rays doses of 50 Mrad and one 1 MeV electron dosage of 3 x 10^{19} e/cm^3 at room temperature; no change in conductivity. Three more irradiated specimens were annealed 1 hr, 1 other annealed at four temperatures up to 1300°C; graph of change of thermal resistivity.	A-1; B-1; C-1; D-1, 4(2); F-4; G-3; O-3; P-2, 4, 6, 8, 13.	A. W. Pryor, R. J. Tainsh, and G. K. White (1964).
deG. -1, 1(a), 2, 2(a)-BeO	. . . . .	#1: sintered under pressure; density of 2.98 g/cm^3. #2: sintered under pressure; density of 2.75 g/cm^3. #1(a) and #2(a): irradiated with 1-2 x 10^{16} neutrons/cm^2 of greater than 1 MeV. Specimen irradiated and then annealed at 500°C gave identical results as #1. Values have been density corrected by factor of: #1, 1%; #2: 9%.	A-1; B-1; C-1; D-1(2); G-3; O-3; P-2, 3, 4, 13.	A. M. de Goër (1965)


MAGNESIUM, CALCIUM, STRONTIUM and BARIUM IONIC CRYSTALS
FIGURE 61
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
M.-1-CaF2
M.-1(a)-CaF2
M.-1(b)-CaF2
M.-2(a)-CaF2
M.-2(b)-CaF2
S.-MgO
S.-1-MgFeAl2O4
M.L.-1-MgO
S.-MgO·3.5Al2O3
M.L.-2-MgO
St.-SrTiO3
S.-MgAl2O4
S.-2-BaTiO3
S.-SrTiO3
S.-1-BaTiO3
McC.B.-BaF2
D.T.-1-Ca3Fe2Si3O12
D.T.-1(a)-Ca3Fe2Si3O12
S.-2-MgFeAl2O4
S.-Mg0.75Fe0.41Al1.85O4
S.-3-MgFeAl2O4
D.T.-1(b)-Ca3Fe2Si3O12

MAGNESIUM IONIC CRYSTALS

(See FIGURES 60b and 61)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	Magnesium sulfate; pressed at 8,000 atm; k = 0.025 at 83 K and 273 K.	. . . . .	A. Eucken and G. Kuhn (1928).
. . . . .	MgO; Norton Co.; Al, Fe, and Si impurities at concentration of $10^{19}/cm^3$.	Cleaved surfaces; maximum thermal conductivity of 8 W/cm-K at 22 K; curve published by G. A. Slack (1962).	. . . . .	A. F. Cohen (1958).
S.-MgO, $MgAl_2O_4$, $MgO \cdot 3.5\ Al_2O_3$, $Mg_{0.75}Fe_{0.41}Al_{1.85}O_4$	MgO: General Electric; $8 \times 10^{18}/cm^3$ Al, $5 \times 10^{16}/cm^3$ Ca and Na, $2.5 \times 10^{18}/cm^3$ Be, $<2.5 \times 10^{18}/cm^3$ K, $8 \times 10^{17}/cm^3$ Si, $<6.3 \times 10^{17}/cm^3$ Zn, $<5 \times 10^{17}/cm^3$ Zr, $4 \times 10^{17}/cm^3$ Cr and Fe, $<4 \times 10^{17}/cm^3$ Ti, $3.1 \times 10^{17}/cm^3$ Li, $<2 \times 10^{17}/cm^3$ Mn and V, $<1.6 \times 10^{17}/cm^3$ Ni. $MgAl_2O_4$: $1.25 \times 10^{20}/cm^3$ Zn, $1.6 \times 10^{19}/cm^3$ Cr, $8 \times 10^{18}/cm^3$ Fe, $6.3 \times 10^{18}/cm^3$ V, $4 \times 10^{18}/cm^3$ Ti, $2 \times 10^{18}/cm^3$ Na, $1.6 \times 10^{18}/cm^3$ Li and Si, $1.25 \times 10^{18}/cm^3$ Mn, $<1.25 \times 10^{18}/cm^3$ Be, $5 \times 10^{17}/cm^3$ Ca and K, $<4 \times 10^{17}/cm^3$ Ni and Zr. $MgO \cdot 3.5\ Al_2O_3$: Linde Air Products; $1.25 \times 10^{19}/cm^3$ Si, $6.3 \times 10^{18}/cm^3$ Fe, $3.1 \times 10^{18}/cm^3$ Ti, $<1.25 \times 10^{18}/cm^3$ Be, $1 \times 10^{18}/cm^3$ Li and Na, $<6.3 \times 10^{17}/cm^3$ Zn, $<5 \times 10^{17}/cm^3$ K, $<4 \times 10^{17}/cm^3$ Cr, Mn, Ni, and V, $2.5 \times 10^{17}/cm^3$ Ca, $<2.5 \times 10^{17}/cm^3$ Zr. $Mg_{0.75}Fe_{0.41}Al_{1.85}O_4$: medium concentration of Ti, low concentration of Cr, Mn, Ni, V, and Zn, trace of Si.	MgO: grown from melt in arc-furnace using self-crucible technique; density of 3.48 g/cm³. transparent, colorless, free of visible defects. Another specimen of MgO also measured. $MgAl_2O_4$: natural crystal from Burma; density of 3.58 g/cm³; transparent, light pink; single crystal octahedra before cut to size; diamagnetic spinel. Another specimen of $MgAl_2O_4$ also measured. $MgO \cdot 3.5\ Al_2O_3$: synthetic spinel, Verneuil process grown. $Mg_{0.75}Fe_{0.41}Al_{1.85}O_4$: natural single crystal from Queensland, Australia; pleonaste spinel, opaque; water worn; in thin section, transparent and yellow-brown; volume of some unidentified second phase inclusions or pores. A specimen of $Mg_{0.73}Fe_{0.33}Al_{1.93}O_4$ measured, with results not more than 10% greater.	A-1; B-1; C-1; D-1(2); E-4; F-5; G-3; O-3; P-5, 8, 11.	G. A. Slack (1962).

MAGNESIUM IONIC CRYSTALS (cont'd)

(See FIGURES 60b and 61)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
S.-1, 2, 3-$MgFeAl_2O_4$	$Mg_{1-x}Fe_xAl_2O_4$. #1 $Mg_{0.99995}Fe_{0.00005}Al_2O_4$; 1 MgO + 1.02 Al_2O_3; 8×10^{18}/cm^3 Ca, 2×10^{18}/cm^3 Si, $<7\times10^{17}$/cm^3 Zn, 5×10^{17}/cm^3 Ti, 4×10^{17}/cm^3 Fe, $<4\times10^{17}$/cm^3 V, $<2\times10^{17}$/cm^3 Cr. #2: $Mg_{0.976}Fe_{0.024}Al_2O_4$; 3.6×10^{20}/cm^3 Fe, 3.5×10^{19}/cm^3 Cr, 2.0×10^{19}/cm^3 Zn, 8×10^{18}/cm^3 V, 5×10^{18}/cm^3 Ti, $<5\times10^{18}$/cm^3 Ca, 4×10^{18}/cm^3 Si. #3: $Mg_{0.73}Fe_{0.19}Al_2O_4$.	#1: synthetic single crystal; prepared by vapor reaction of MgO with Al_2O_3; nearly stoichiometric spinel; colorless in bulk; crystallite diameter of 0.3 cm. #2: natural crystal from Ceylon; bluish-purple in bulk. #3: natural crystal from Australia; opaque, yellowish brown thin sections.	A-1; B-1; C-1; D-1(2); E-4; F-5; G-3; O-3; P-5, 7, 8; S-4.	G. A. Slack (1964).
C. W.-1, 1(a), 1(b)-MgO	MgO; doped with 0.3 Cr; 100 ppm Fe, <20 ppm V, 10 ppm Mn, <5 ppm Co, <2 ppm Cu and Ni.	Rod axis perpendicular to [001] direction. #1: unirradiated. #1(a): transverse magnetic field of 0.2 T. #1(b): transverse magnetic field of 0.7 T. Also measured in fields of 0.1 and 0.4 T with intermediate results. Also measured another unirradiated specimen.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-3; O-5; P-7.	L. J. Challis and D. J. Williams (1965).
C. McC. W.-1, 1(a), 2, 2(a)-MgO	#1: 3-22.8 ppm Cr, 20 ppm Fe, 14 ppm Mn, 1.2 ppm V. #2: 2800-3000 Cr, 55-100 ppm Fe, 20 ppm V, 1-10 ppm Mn, 5 ppm Co, 2 ppm Cu and Ni; doped with Cr.	Cleaved with axes parallel to ⟨100⟩ direction. #1: as received; clear, colorless; emitted white light at 420 K; 0.3 x 0.3 x 0.63 cm size. #1(a): irradiated 3 hrs with x-rays produced by 16 mA. beam of 38 kV electrons; precooled to nitrogen temperatures with 5 hrs; violet color. #2: as received; doped with Cr; 0.4 x 0.4 x 0.73 cm size; dark green. #2(a): heated 24 hrs at 1650 K in reducing atmosphere of N_2 + 10% H_2; cooled to room temperature in 8 hrs. Three other crystals in various conditions of as received, heat treated, and irradiated, also measured.	A-1; B-2; C-1; D-3(2); E-3, 5; F-4; G-3; O-9; P-2, 5, 7, 10; Q-5.	L. J. Challis, M. A. McConachie, and D. J. Williams (1968).

MAGNESIUM IONIC CRYSTALS (cont'd)

(See FIGURES 60b and 61)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	MgO.	Measured C. McC. W. specimens in longitudinal magnetic field of 5. 3 T and transverse magnetic field of 2. 1 T.	. . . . .	L. J. Challis, M. A. McConachie, and D. J. Williams (1969).
L. M. - 1, 2-MgO	Spicer Ltd. #1: 99. 9 nominally pure. #2: MgO: Fe^{++}, 90% of Fe in the divalent state; 7500 ppm Fe.	#2: grown by arc-fusion technique. Two other specimens with 300 and 300 ppm Fe also measured, with intermediate results.	A-1; B-1; C-1; D-1(2); E-1; F-4; G-3; O-2, 3; P-2, 5, 7, 10, 12.	I. P. Morton and M. F. Lewis (1971); see also Lewis and Morton (1968).
. . . . .	. . . . .	Measured thermal conductivity of two natural magnesium single crystal garnets between 3 and 300 K. See Minerals Table.	. . . . .	G. A. Slack and D. W. Oliver (1971).

CALCIUM IONIC CRYSTALS

(See FIGURES 60a, 60b, and 61)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Marble ($CaCO_3$).	Marble: #1, small crystals, 99.9% $CaCO_3$; k = 0.042 at 83 K; k = 0.033 at 273 K; #2, 99.99% $CaCO_3$; k = 0.054 at 83 K; k = 0.038 at 273 K; #3, large crystals; k = 0.050 at 83 K; k = 0.033 at 273 K. Calcite: #1, rod axis perpendicular to main crystal axis; k = 0.180 at 83 K; k = 0.046 at 273 K; #2, rod axis parallel to main crystal axis; k = 0.293 at 83 K; k = 0.054 at 273 K.	. . . . .	A. Eucken and G. Kuhn (1928).
. . . . .	CaF_2.	Cleaved surfaces; maximum thermal conductivity of 40 W/cm-K at 16 K.	. . . . .	A. F. Cohen (1958).
McC. B. -CaF_2	Optovac Co.	. . . . .	A-6; B-1; C-1; D-1(3); F-5; G-3.	K. A. McCarthy and S. S. Ballard (1960).
S. -CaF_2	Harshaw Chemical Co.; 4×10^{18}/cm^3 Sr, 2.5×10^{18}/cm^3 Li, 2×10^{18}/cm^3 Be, 1.25×10^{18}/cm^3 Aℓ, $<1 \times 10^{18}$/cm^3 Ni, 8×10^{17}/cm^3 Na, $<4 \times 10^{17}$/cm^3 Fe and Mg, $<1.6 \times 10^{17}$/cm^3 Mn, $<1 \times 10^{17}$/cm^3 Pb.	Cubic; diamagnetic; density of 3.181 g/cm^3.	A-1; B-1; C-1; D-1(3); E-1, 4; F-5; G-3; O-3; P-2, 5, 8.	G. A. Slack (1961).
H. -1, 2-$CaWO_4$	#1: 0.01 Nd. #2: 0.50 Nd, 0.001-0.01 Si.	Single crystals. #1: rod axis parallel to c-axis. #2: rod axis perpendicular to c-axis.	A-1; B-1; C-1; D-1(2); E-4; F-4; G-3; O-3; P-2, 5, 12.	M. G. Holland (1962).
M. -1, 1(a), 1(b), 2(a), 2(b)-CaF_2	Harshaw Chemical Co.; >5 Ca, <1 ppm Aℓ, Cu, Fe, and Si.	Cleavage system of {111}. #1: rod axis parallel to [110]. #1(a): compressed 4% along $[1\bar{2}1]$ axis at 270°C for 10 min, cooled several hours to room temperature; cut; rod axis parallel to edge dislocations. #1(b): same as #1(a), except compressed 7%. #2(a): same as #1(a) except rod axis perpendicular to edge dislocations. #2(b): same as #1(b), except rod axis perpendicular to edge dislocations.	A-1; B-1; C-1; D-3(2); E-3, 4, 5; F-4; G-3; O-3; P-3, 5, 9.	M. Moss (1965).

CALCIUM IONIC CRYSTALS (cont'd)

(See FIGURES 60a, 60b, and 61)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
D. T. -1, 1(a), 1(b)- $Ca_3Fe_2Si_3O_{12}$	"Pure" and "Analar" grade oxides. #1: $Ca_3Fe_2Si_3O_{12}$. #1(a): 0.60 $Ca_3Fe_2Si_3O_{12}$ - 0.40 $Y_3Fe_5O_{12}$. #1(b): 0.82 $Ca_3Fe_2Si_3O_{12}$ - 0.18 $Y_3Fe_5O_{12}$.	Calcium-yttrium garnets prepared by solid-state reaction. Annealed near 1250°C, mixed several times with grinding and pressing; second phase did not exceed 3-4%. #1: density of 3.28 g/cm^3; paramagnetic. #1(a): density of 4.05 g/cm^3; antiferromagnetic below 302 K, paramagnetic above. #1(b): antiferromagnetic below 130 K, paramagnetic above.	A-1; B-1; C-1; D-1(2); F-4; G-2; O-3; P-9, 10, 12.	E. D. Devyatkova and V. V. Tikhonov (1967).
K. -$CaWO_4$	Prepared from Sylvania Crystal Grade Ca and $NaWO_4$; doped with 0.5(mole) Nd from >99.99 NdO_2; 6×10^{19}/cm^3 Na and Nd.	Cut from single crystal; grown by Czochralski technique from melt containing 0.5%(mole) Nd and Na; pulled at rate of 1 cm/hr; annealed 24 hrs in air at 1200°C. Rod axis parallel to c axis.	A-1; B-1; C-1; D-1(2); E-3; F-4; G-3; O-3; P-2; S-3.	P. H. Klein (1967).
. . . . .	. . . . .	Measured thermal conductivity of three natural calcium single crystal garnets between 3 and 300 K. See Minerals Table.	. . . . .	G. A. Slack and D. W. Oliver (1971).

STRONTIUM IONIC CRYSTALS

(See FIGURES 60a, 60b, and 61)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	$SrTiO_3$.	Pulverized; pressed at 1400°C for 8 hrs at 0.53 ton (metric)/cm^2; density of 4.01 g/cm^3; k = 0.045 at -180°C; k = 0.025 at 8°C.	A-1; B-1; C-1; D-1(2); F-2; G-3; O-3.	I. Yoshida (1960).
S. P. -1, 1(a)-$SrTiO_3$	. . . . .	Single crystal strontium titanate. #1: unaltered. #1(a): applied d. c. electric of 16.8 kV/cm field along [100] axis perpendicular to rod axis; applied between gold films evaporated on opposite crystal faces.	A-1; B-1; C-1; D-1(2); E-4, 8; F-4; G-3; O-3, 9; P-2, 5, 7, 12.	A. J. Sievers and R. O. Pohl (1964).
S. -$SrTiO_3$	Fuji Titanium Industry Co.	Single crystal; obtained by flame-fusion method; colorless and transparent; paraelectric. Rod axis parallel to (100); transition temperatures at 35, 65, and 110 K.	A-1; B-1; C-1; D-1(2); E-1, 4; F-4; G-3; O-3; P-5, 9.	Y. Suemune (1965).
St. -$SrTiO_3$	National Lead; <200 ppm W, 20 ppm SiO_2 10 ppm Fe_2O_3, 1 ppm $A\ell_2O_3$, <1 ppm Sb_2O_3, <0.1 ppm Cr, Cu, Mg, Mn, Pb, V, and SnO_2.	Single crystals; annealed 24 hrs at 1400°C; (100) oriented faces; Perovskite structure. Also measured in electric field of 46 kV/cm; field directed perpendicular to rod axis and in (100) direction; at 5 K, the thermal conductivity is doubled.	A-1; B-1; C-1; D-1(2); E-3, 4; F-4; G-3; O-9; P-5, 7, 8.	E. F. Steigmeier (1968).

BARIUM IONIC CRYSTALS

(See FIGURE 61)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	$Ba(NO_3)_2$.	$Ba(NO_3)_2$; pressed at 8,000 atm; k = 0.033 at 83 K; k = 0.013 at 273 K.	. . . . .	A. Eucken and G. Kuhn (1928).
. . . . .	$BaTiO_3$.	Pulverized; pressed at 1300°C for 6.5 hrs by 1.3 tons (metric)/cm^2; sintered; ferroelectric; density of 5.03 g/cm^3; phase transitions at -90 and 5°C; k = 0.020 at -185 K; k = 0.022 at -57°C; k = 0.024 at 3°C.	A-1; B-1; C-1; D-1(2); F-2; G-3; O-3.	I. Yoshida (1960).
McC. B. -BaF_2	Optovac Co.	. . . . .	A-6; B-2; C-1; D-1(3); F-5; G-3.	K. A. McCarthy and S. S. Ballard (1960).
S. -1, 2-$BaTiO_3$	Kinsekisha Laboratory. #1: starting materials contained 0.02(weight) Fe_2O_3 as major impurity.	Ferroelectric; rhombohedral up to 193 K, orthorhombic to 273 K, above 273 K is tetragonal. #1: single crystal; grown by flux method; rod axis parallel to (100). #2: ceramic of $BaTiO_3$; prepared by sintering process.	A-1; B-1; C-1; D-1(2); E-1, 4; F-4; G-3; O-3; P-5, 9.	Y. Suemune (1965).
. . . . .	Mass. Inst. Tech. 600 ppm Ca; < 5 ppm Pt; 10 ppm Mg; 7 ppm Sn; 5 ppm Si.	Single crystal, ⟨100⟩ and ⟨112⟩, specimens of barium titanate pulled from a $BaO-TiO_2$ melt containing a surplus of TiO_2. Transition temperatures at 200 K and 283 K higher than for crystals grown by flux methods. Thermal conductivity dips at the transition temperatures. Maximum conductivity of 1.2 watts/cm K at 30 K. Graphs of effect of polarizing electric field.	A-1; B-1; C-1; D-1(2); F-4; G-3; O-3, 9; P-4, 5, 7.	A. J. H. Mante and J. Volger (1971). Also (1967).

YTTRIUM IONIC CRYSTALS

(See FIGURE 62a)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Yttrium iron garnets; Westinghouse.	Specimen size 0.1 x 0.1 x 1 cm. #1: rod axis parallel to (210) direction; k = 0.006 at 1.43 K; k = 0.050 at 4.2 K; intermediate values also measured. #2: rod axis parallel to (321) direction; k = 0.0056 at 1.43 K; k = 0.044 at 4.2 K; intermediate values also measured. Also measured in longitudinal magnetic field of 0.03 T and transverse magnetic field of 0.8 T.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-3; O-5, 6; P-2; Q-5; R-2.	B. Lüthi (1962).
D. -1, 2-YIG	YIG: yttrium iron garnet; ~0.1 Pb. #1: Microwave Chemicals Lab. #2: Airtron Div.	Cut from a single crystal; grown from slowly cooled melt; several holes up to 0.1-0.6 mm; surfaces ground with 600 mesh SiC. #1: 0.35 x 0.38 x 1.22 cm. #2: 0.16 x 0.46 x 1.27 cm. Also measured in transverse and longitudinal magnetic field of up to 1.8 T.	A-1; B-1; C-1; D-3(2); E-6; F-4; G-3; P-2, 10; R-2.	R. L. Douglass (1963).
D. T. -1, 1(a)-$Y_3Fe_5O_{12}$	"Pure" and "Analar" grade oxides. #1: $Y_3Fe_5O_{12}$. #1(a): 0.667 $Y_3Fe_5O_{12}$ -0.333 $Ca_3FeSi_3O_{12}$.	Antiferromagnetic. Yttrium-calcium garnets prepared by solid-state reaction. Annealed at 1450°C and mixed, several times, with grinding and pressing. No second-phase of more than 3%. #1: density of 5.00 g/cm^3. #1(a): density of 4.49 g/cm^3.	A-1; B-1; C-1; D-1(2); F-4; G-2; Q-3; P-9, 10, 12.	E. D. Devyatkova and V. V. Tikhonov (1967).
. . . . .	$Y_{1.98}Nd_{0.02}O_3$; 1(mole)Nd_2O_3.	Single crystal; prepared by the flame-fusion process; k = 0.59 at 80 K; k = 0.20 at 200 K; k = 0.14 at 252 K.	A-1; B-1; C-1; D-1(2); F-4; G-3; O-3; P-2; S-3.	P. H. Klein (1967).
. . . . .	. . . . .	Measured thermal conductivity of four yttrium-aluminum, one - gallium, and four - iron sincle-crystal garnets between 3 and 300 K.	. . . . .	G. A. Slack and D. W. Oliver (1971).

TITANIUM IONIC CRYSTALS

(See FIGURES 56b, 62b, and 62c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
B. F. Z. -TiO_2	Linde Air Products.	TiO_2 (rutile).	A-1; B-1; C-1; D-2, 4(2); E-4; F-4; G-3; O-3; P-2, 8.	R. Berman, E. L. Foster, and J. M. Ziman (1956).
T. M. -1, 1(a), 2-TiO_2	#1: National Lead Co.; 0.0001-0.001 Ba, Cu, and Si, smaller quantities of Aℓ, Ca, and Fe; chemical impurities of 10^{17}-10^{18}/cm^3. #1(a): carrier concentration of 10^{20}/cm^3. #2: National Lead Co.; doped with 0.1(weight)Nb_2O_5, concentration of 1.6×10^{19}/cm^3 Nb-ion.	TiO_2 (rutile). #1: single crystal; cut from boule grown by Verneuil method; oxidized 2 days in air at 700°C; surfaces roughened with SiC paper with No. 600 for final finish; rod axis parallel to crystal a-axis. Identical specimen with rod axis parallel to crystal c-axis also measured, with results 50% greater than #1 above 25 K, reducing to 5% greater below 25 K. #1(a): same as #1, then hydrogen-reduced by heating in flowing H_2 gas for 2 hrs at 900°C; furnace cooled to near room temperature in 2-3 hrs; also semiconductor above room temperature. #2: Nb-doped TiO_2; cut from boule grown from rutile powder containing 0.1% (weight) Nb_2O_5; also semiconductor above room temperature. Measurements on variously-treated specimens also conducted, with intermediate results.	A-1; B-1; C-1; D-1(2); E-3; F-4; G-3; O-3, 5, 6; P-2, 5, 8; S-2.	W. R. Thurber and A. J. H. Mante (1965).
R. W. -1, 2, 3-TiC	Linde; metallic impurity of carbide crystals <0.1(atomic); <0.01(weight) O_2 and N_2. #1: $TiC_{0.83}$. #2: $TiC_{0.90}$. #3: $TiC_{0.96}$.	Cut from single-crystal boules grown by arc-Verneuil process; crystallized in rocksalt structure; some low-angle boundaries and grown-in dislocations present at density of 10^6/cm^2. #1: ground surface. #2: cleaved surface. #3: ground surface. Two other specimens also measured, with intermediate results. One specimen measured to study effect of ground surfaces. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-1(2); G-3; L-1; M-1; O-3; P-2, 3, 4, 11; Q-1.	L. G. Radosevich and W. S. Williams (1969a) and (1969b).

TITANIUM IONIC CRYSTALS (cont'd)

(See FIGURES 56b, 62b, and 62c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
M.V.-1, 1(a), 2, 2(a), 3- TiO_2	National Lead. #3: 400 ppm Si.	Grown by flame-fusion technique; specimen size of 0.9 x 4 x 20 mm. #1: oxidized 24 hrs at 1130°C; maximum of k = 14.4 at 14.7 K. #1(a): vacuum reduced 27.5 hrs at 1170°C. #2: vacuum reduced 19 hrs at 1120°C; also semiconducting material. #2(a): reoxidized 24 hrs at 700°C. #3: vacuum reduced 19 hrs at 1080°C. Also measured 12 other specimens with oxidation, reduction, reoxidation, and silicon dopings.	A-1; B-1; C-1; D-1(2); E-3; F-4; G-3; O-2, 3; P-2, 3, 5, 6, 9; S-1.	A. J. H. Mante and J. Volger (1970).
B.S.S-1, 2, 3- TiO_2	#1: stochiometric. #2: doped with Cr, $1.4 \times 10^{19}/cm^3$ Cr atoms. #3: carrier concentration of $4.6 \times 10^{18}/cm^3$.	Single crystal; prepared by Verneuil method; rod axis parallel to a-axis. #1: transparent, yellow tinge. #2: also semiconducting material. #3: annealed in air, then annealed in hydrogen 1 hr at 600°C; blue; also semiconducting material.	A-1; B-1; C-1; D-1(2); E-1; F-4; G-3; O-3, 9; R-5; S-1, 2.	V. N. Bogomolov, I. A. Smirnov, and E. V. Shadrichev (1970).

ZIRCONIUM IONIC CRYSTALS

(See FIGURE 62a)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
R.W.-ZrC	Linde; $ZrC_{0.88}$; metallic impurity of carbide crystal <0.1(atomic); <0.01(weight) O_2 and N_2.	Cleaved from single-crystal boule grown by arc-Verneuil process; crystallized in rock-salt structure; some low-angle boundaries and grown-in dislocations at density of $10^6/cm^2$. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-1; G-3; L-1; M-1; O-3; P-2, 3, 4, 11; Q-1.	L.G. Radosevich and W.S. Williams (1969a).
M.S.-ZrC	Wah Chang Corp.; 87.1 Zr, 11.2 total C, 0.6 free C, 0.6 O_2, <200 ppm Hf, <100 ppm Cr, Mo, and Nb, <30 ppm Ba, Co, K, Sr, and Ti, <10 ppm Aℓ, Bi, Cu, Ni, Pb, Si, and Sn, <3 ppm Ag, B, Ca, Li, Mn, and Na, <1 ppm Be and Mg.	Hot-pressed at 3000 K for 10 min, 225 atm. Density of 6.26 g/cm^3. Calculated from thermal diffusivity measurements. Disc axis parallel to longitudinal axis of hot pressed cylinder.	A-2; B-4; L-1; M-1; P-1.	B.H. Morrison and L.L. Sturgess (1970).

NIOBIUM IONIC CRYSTALS

(See FIGURE 62b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
R.W.(1)-NbC	Linde; $NbC_{0.76}$; metallic impurity content of carbide crystals <0.1(atomic); <0.01(weight) O_2 and N_2.	Cleaved from single-crystal boule grown by arc-Verneuil process; crystallized in rock-salt structure; some low-angle boundaries and grown-in dislocations at density of $10^6/cm^2$. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-1; G-3; L-1; M-1; O-3; P-2, 3, 4, 11; Q-1.	L.G. Radosevich and W.S. Williams (1969a).
R.W.(2)-1, 1(s)-NbC	Ventron Electronics; $NbC_{0.96}$.	Measured in both the normal and superconducting (s) states. T_c = 9.8 K. Values in superconducting state below 4 K: 0.30 at 3.5 K; 0.31 at 3.1 K; 0.32 at 2.9 K; 0.28 at 2.5 K; 0.204 at 2 K; 0.109 at 1.6 K. Graph of electronic and lattice thermal conductivity. Graph of ratio of lattice thermal conductivity in superconducting and normal states as a function of reduced temperature.	A-1; B-1; C-1; D-1; G-3; L-1; M-1; N-3; O-3; P-2, 3, 4, 11; Q-1.	L.G. Radosevich and W.S. Williams (1969c).
M.S.-NbC	Wah Chang Corp.; 88.4 Nb, 11.2 total C, <500 ppm free C, 0.13 O_2, 2000 ppm W, 500 ppm Ta, 200 ppm Ti, 170 ppm N_2, 50 ppm Cr, Mo, and Zr, <30 ppm Ba, Co, K, and Sr, <10 ppm Aℓ, Bi, Cu, Ni, Pb, Si, Sn, and V, <3 ppm Ag, B, Ca, Li, Mn, and Na, <1 ppm Be and Mg.	Hot-pressed at 3300 K for 10 min at 225 atm. Density of 7.52 g/cm^3. Calculated from thermal diffusivity measurements. Disc axis parallel to longitudinal axis of hot pressed cylinder.	A-2; B-4; L-1; M-1; P-1.	B.H. Morrison and L.L. Sturgess (1970).

MANGANESE IONIC CRYSTALS

(See FIGURES 62a-62c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
S. N. -MnO	Starting material reagent grade $MnCo_3$.	Single crystals; grown by Verneuil process; possible strains present; small deviation from stoichiometry may exist; antiferromagnetic below 120 K, paramagnetic above.	A-1; B-1; C-1; D-1(2); E-4; F-5; G-3; O-3, 5; P-9, 15; Q-5; S-1.	G. A. Slack and R. Newman (1958).
D. F. -1, 2- $MnFe_2O_4$	Linde Air Products. #1: $MnFe_2O_4$; 38.4(weight) Fe, 33.7 Mn. #2: $Mn(Zn)Fe_2O_4$; 49.2 Fe, 20.95 Mn, 6.17 Zn.	Single crystals; spinel structure; cut from rough single-crystal boule prepared by flame fusion technique; ground; nonuniform composition. #1: manganese ferrite; rod axis parallel to $[\bar{4}10]$ axis; also measured between 1 and 4 K in longitudinal magnetic field of 0.94 T, with results less than 10% greater than when in no magnetic field. #2: manganese-zinc ferrite; rod axis parallel to $[\bar{2}52]$ axis; also measured between 1 and 4 K in magnetic field, with identical results.	A-1; B-1; C-1; D-3(2); E-5; F-5; G-3; P-5; Q-5; R-2; S-1, 4.	D. Douthett and S. A. Friedberg (1961).
S. -1, 2- MnF_2	$5 \times 10^{19}/cm^3$ Mg, $<2.5 \times 10^{18}/cm^3$ Be, $2 \times 10^{18}/cm^3$ Al, $<1.6 \times 10^{18}/cm^3$ Li, $1.25 \times 10^{18}/cm^3$ Fe, $1 \times 10^{18}/cm^3$ Na, $5 \times 10^{17}/cm^3$ Ca, $<5 \times 10^{17}/cm^3$ Ni, $<2.5 \times 10^{17}/cm^3$ Sr, $<1.25 \times 10^{17}/cm^3$ Pb.	Antiferromagnetic crystals below 67 K, paramagnetic above. Tetragonal structure. #1: rod axis parallel to a-axis. #2: rod axis parallel to c axis. Density of 3.925 g/cm^3. Also measured another specimen similar to #1, with identical results.	A-1; B-1; C-1; D-1(3); E-1, 4; F-5; G-3; O-3, 6; P-2, 5, 8, 10; R-2.	G. A. Slack (1961).
Su. -1, 2- $Mn_xFe_{3-x}O_4$	#1: $Mn_{1.05}Fe_{2.95}O_4$. #2: $MnFe_2O_4$.	Single crystals; spinel structure; grown in air by Bridgmann technique; manganese ferrites. Two other specimens also measured.	O-3; P-1; S-1.	Y. Suemune (1966a).
Su. -$Mn_{0.5}Zn_{0.5}Fe_2O_4$	. . . . .	Mixed manganese ferrite.	Same as above.	Same as above.

IRON IONIC CRYSTALS

(See FIGURE 62c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	$MnFe_2O_4$ and $Co(Zn)Fe_2O_4$.	See MANGANESE and COBALT IONIC CRYSTAL Table.	. . . . .	D. Douthett and S. A. Friedberg (1961).
S.-1, 2, 3-Fe_3O_4	#1 and #2: $<1.2 \times 10^{18}/cm^3$ Be, $1.25 \times 10^{18}/cm^3$ Al and Na, $<1.25 \times 10^{18}/cm^3$ Li, $<1 \times 10^{18}/cm^3$ Si and Zn, $<8 \times 10^{17}/cm^3$ Ca and K, $6.3 \times 10^{17}/cm^3$ Cr, $<6.3 \times 10^{17}/cm^3$ Ti and V, $4 \times 10^{17}/cm^3$ Mg and Ni, $<3.1 \times 10^{17}/cm^3$ Zr, $1.25 \times 10^{17}/cm^3$ Mn. #3: $Co_{0.07}Fe_{2.93}O_4$; 2.4 Fe^{2+} replaced by Co^{2+}.	Single crystals; inverse spinel structure; grown from the melt using the Czochralski technique; opaque, black luster; ferrimagnetic-orthorhombic below 119 K, inverse spinel above; no second inclusions of FeO or Fe_2O_3. #1 and #2: density of 5.19 g/cm^3; orthorhombic crystal structure. #3: $Co_{0.07}Fe_{2.93}O_4$; impure Fe_3O_4; transition temperature of 110 K, with same phase transition as #1.	A-1; B-1; C-1; D-1(2); E-4; F-2; G-3; O-3, 5; P-5, 8, 10, 11; S-1.	G. A. Slack (1962).
S. S. I.-Fe_3O_4	Shabry in the Urals.	Natural magnetite; ferromagnetic; rod axis parallel to [111] direction. Graph of relative change in thermal conductivity as a function of magnetic field strength up to 1 T for different field directions.	A-1; B-3; C-1; D-3(2); E-3, 5; G-3; P-1; Q-5; R-2.	V. L. Sedov, L. V. Solomatina, and L. N. Il'chenko (1963).
S.-$FeAl_2O_4$	Starting materials of Johnson-Matthey "Specpure" oxides; $7 \times 10^{18}/cm^3$ Si, $3 \times 10^{18}/cm^3$ Cr, $1 \times 10^{18}/cm^3$ Ti, $<8 \times 10^{17}/cm^3$ Zn, $<7 \times 10^{17}/cm^3$ Ca, $3 \times 10^{17}/cm^3$ Mg and V.	Single crystal; grown in CO/CO_2 atmosphere in pure iridium crucible by modified Bridgmann technique; surrounded with high-purity Al_2O_3 powder and sealed in high-purity iron capsule; annealed 21 hrs at 1200°C; normal spinel structure; opaque in bulk, greenish-yellow in thin sections. Possible antiferromagnetic transition at transition temperature of 10.5 K. Another specimen, as-grown, measured, with results less than 10% greater at 10 K.	A-1; B-1; C-1; D-1(2); E-4; F-2; G-3; O-3; P-5, 7, 8; S-4.	G. A. Slack (1964).
Su.-$Fe_{0.5}Zn_{0.5}Fe_2O_4$	. . . . .	Single crystal; spinel structure; grown in air by Bridgmann technique; mixed iron ferrite.	P-1; S-1.	Y. Suemune (1966a).
. . . . .	. . . . .	Measured thermal conductivity of two iron garnets between 3 and 300 K. See Minerals Table. Also measured four synthetic yttrium-iron garnets.	. . . . .	G. A. Slack and D. W. Oliver (1971).

ISCONIM - ERL

RUTHENIUM IONIC CRYSTAL

(See FIGURE 62a)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
M. -RuO_2	RRR = 115.	Grown using oxygen-transport deposition; specimen size of 0.09 x 0.165 x 4.0 mm; rod axis parallel to c-axis.	A-1; B-1; C-1; D-1(2); G-3; L-1; M-1; S-5.	J. Millstein (1970).

NICKEL IONIC CRYSTAL

(See FIGURES 62b and 62c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
S. N. -NiO	Starting material reagent grade $NiCO_3$.	Single crystal; grown by Verneuil process; no large-angle grain boundaries; possible strains.	A-1; B-1; C-1; D-1(2); E-4; F-5; G-3; O-3, 5; P-9, 15; Q-5; S-1.	G. A. Slack and R. Newman (1958).
K. -$Ni_{0.3}Zn_{0.7}Fe_2O_4$	. . . . .	Ferrite.	A-1, 6; B-4; E-3; G-3; P-1.	I. K. Kamilov (1963).

COPPER IONIC CRYSTALS

(See FIGURE 62b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Copper sulfate	Copper sulfate; k = 0.029 at 83 K; k = 0.021 at 273 K.	. . . . .	A. Eucken and G. Kuhn (1928).
See FIGURE 75	. . . . .	$CuSO_4 \cdot 5H_2O$, measured below 1 K.	. . . . .	A. R. Miedema, J. N. Haasbroek, and F. W. Gorter (1965).
. . . . .	. . . . .	Graphs of lattice thermal conductivity of the Cu_2SnSe_3-Cu_2GeSe_3 system and Cu_2SnS_3-Cu_2GeS_3 system. See also Table and FIGURE 56a for COPPER SEMICONDUCTORS.	. . . . .	T. Irie, S. Endo, and I. Sudo (1970); see also Irie and Endo (1969).
See FIGURE 75	$Cu(NH_4)_2Br_4 \cdot 2H_2O$.	Three-dimensional Heisenberg ferromagnet; T_c = 1.74 K. In zero magnetic field: k = 0.00126 at 1.03 K; k = 0.0012 at 1.08 K; k = 0.00124 at 1.26 K; k = 0.00128 at 1.4 K; k = 0.0014 at 1.5 K; k = 0.00145 at 1.6 K; k = 0.00155 at 1.7 K; k = 0.00186 at 1.8 K; k = 0.00204 at 1.9 K; k = 0.00245 at 2 K; k = 0.00262 at 2.2 K; k = 0.00346 at 2.4 K; k = 0.00398 at 2.5 K; k = 0.0053 at 2.8 K. In transverse magnetic field of 1 T; k = 0.00195 at 1.06 K; k = 0.00199 at 1.35 K; k = 0.00224 at 1.62 K; k = 0.00295 at 2.1 K; k = 0.00436 at 2.45 K. Also measured below 1 K.	A-1; B-1; C-1; D-3(2); G-3; Q-5; R-2.	J. N. Haasbroek and A. S. M. Gieske (1970).
H. H. - $Cu(NH_4)_2Cl_4$; also see FIGURE 75	$Cu(NH_4)_2Cl_4 \cdot 2H_2O$.	Cut from single crystal; grown from aqueous solution; ferromagnet; transition temperature of 0.70 K; rod axis parallel to c-axis; specimen size of 2.3 x 2.7 x 17.7 mm. Also measured in magnetic field of up to 1.1 T. Also measured below 1 K.	A-1; B-1; C-1; D-3(2); G-2; P-7, 10; Q-5; R-2.	J. N. Haasbroek and W. J. Huiskamp (1970).

SILVER IONIC CRYSTAL

(See FIGURE 62b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
McC. B. -$AgCl_2$	. . . . .	Drawn from melt of silver chloride powder.	A-6; B-2; C-1; D-1(3); F-5; G-3.	K. A. McCarthy and S. S. Ballard (1960).
. . . . .	. . . . .	Graph of lattice thermal conductivity of $AgBiSe_2$.	. . . . .	T. Irie, S. Endo, and I. Sudo (1970).

ZINC IONIC CRYSTAL

(See FIGURE 62a)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
R.S.-1, 2, 3, 4, 5-$ZnSO_4$	$ZnSO_4 \cdot 7H_2O$; Analar grade; 0.006 max. impurities. #1: pure. #2: mixed with 0.25 $FeSO_4$. #3: mixed with 1.0 $FeSO_4$. #4: mixed with 5.6 $FeSO_4$. #5: mixed with 5.77 $MgSO_4$.	Specimen size 0.3 x 0.4 x 3 cm.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-3; O-3; P-2, 5, 8, 10, 12.	H.M. Rosenberg and B. Sujak (1960).
S.-ZnF_2	General Electric Research Laboratory; $1.6 \times 10^{19}/cm^3$ Ni, $1.2 \times 10^{19}/cm^3$ Fe, $<6.25 \times 10^{18}/cm^3$ Na, $2.5 \times 10^{18}/cm^3$ Be and Li, $1.25 \times 10^{18}/cm^3$ Aℓ and Mn, $<1.25 \times 10^{18}/cm^3$ Mg, $8 \times 10^{17}/cm^3$ Ca, $3.1 \times 10^{17}/cm^3$ Pb.	Diamagnetic. Rod axis inclined 74° from the c-axis. Tetragonal structure. Density of 4.952 g/cm^3. Transition temperature of 74 K.	A-1; B-1; C-1; D-1(2); E-1, 4; F-5; G-3; O-3; P-2, 5, 8.	G.A. Slack (1961).
Su.-1, 2-$ZnSO_4$	Starting materials "Analar" purity grade, <0.006. #1: 0.25(weight) $FeSO_4$ added. #2: 1 $FeSO_4$ added.	Single crystal $ZnSO_4 \cdot 7H_2O$, zinc sulphate hydrate; cut. #1: remeasured several times, after allowing specimen warmup, wetting with distilled water, dried with absorbent paper, acetone added to chamber, and dry air; each successive measurement resulted in lower values at 4 K, and identical values at 20 K.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-3; O-3; P-2, 3, 4, 5, 10, 11.	B. Sujak (1961).

COBALT IONIC CRYSTAL

(See FIGURES 62a-62c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
D. F. -Co(Zn) Fe_2O_4	55.8(weight) Fe, 11.6 Co, 6.46 Zn.	Single crystal cobalt-zinc ferrite; cut from rough boule prepared by flame fusion technique; ground; of nonuniform composition; rod axis parallel to $[5\bar{3}4]$ direction. Also measured between 1 and 4 K in longitudinal magnetic field, with results less than 25% greater.	A-1; B-1; C-1; D-3(2); E-5; F-5; G-3; P-5; Q-5; R-2; S-1, 4.	D. Douthett and S. A. Friedberg (1961).
S. -CoF_2	General Electric Research Laboratory; $2.5 \times 10^{20}/cm^3$ Ni, $1.6 \times 10^{20}/cm^3$ Ca and Mg, $8 \times 10^{19}/cm^3$ Fe, $2.5 \times 10^{19}/cm^3$ Mn, $1.6 \times 10^{19}/cm^3$ Pb, $6.3 \times 10^{18}/cm^3$ Al, $<2 \times 10^{18}/cm^3$ Li, $1.25 \times 10^{18}/cm^3$ Na, $<1.25 \times 10^{18}/cm^3$ Be, $<2.5 \times 10^{17}/cm^3$ Sr.	Single crystal; rod axis inclined 26° to the c-axis; tetragonal; density of 4.592 g/cm^3. One other specimen also measured; transition temperature of 38 K; antiferromagnetic below 38 K, paramagnetic above.	A-1; B-1; C-1; D-1(2); E-1, 4; F-5; G-3; O-3; P-2, 5, 8, 10; R-2.	G. A. Slack (1961).
S. -$CoAl_2O_4$	. . . . .	Single crystal; normal spinel; grown by flame-fusion method; annealed in air 100 hrs at 1000° C. As-grown specimen had same values.	A-1; B-1; C-1; D-1(2); E-4; F-2; G-3; O-3; P-5, 7, 8; S-4.	G. A. Slack (1964).
See FIGURE 75	$CoCs_3Cl_5$.	Three-dimensional Ising antiferromagnet; $T_c = 0.53$ K. In zero magnetic field: k = 0.0042 at 1.5 K; k = 0.0051 at 1.65 K; k = 0.0065 at 1.8 K. In transverse magnetic field of 1 T: k = 0.0026 at 1.08 K; k = 0.0042 at 1.45 K; k = 0.0052 at 1.55 K; k = 0.0074 at 1.8 K; k = 0.0098 at 2.1 K. Also measured below 1 K.	A-1; B-1; C-1; D-3(2); G-3; Q-5; R-2.	J. N. Haasbroek and A. S. M. Gieske (1970).

BORON IONIC CRYSTAL

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	Boron trifluoride.	From 85 to 130 K, the average value was 0.0042 ± 0.00025.	. . . . .	E. J. Burton, P. J. Stokes, and A. B. Murphy (1958).

ALUMINUM GARNETS

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	Measured thermal conductivity of 14 rare earth-aluminum single crystal garnets between 3 and 300 K.	. . . . .	G. A. Slack and D. W. Oliver (1971).

GALLIUM GARNETS

CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	Measured thermal conductivity of ten rare earth - gallium single-crystal garnets between 3 and 300 K.	. . . . .	G. A. Slack and D. W. Oliver (1971).

GERMANIUM IONIC CRYSTAL

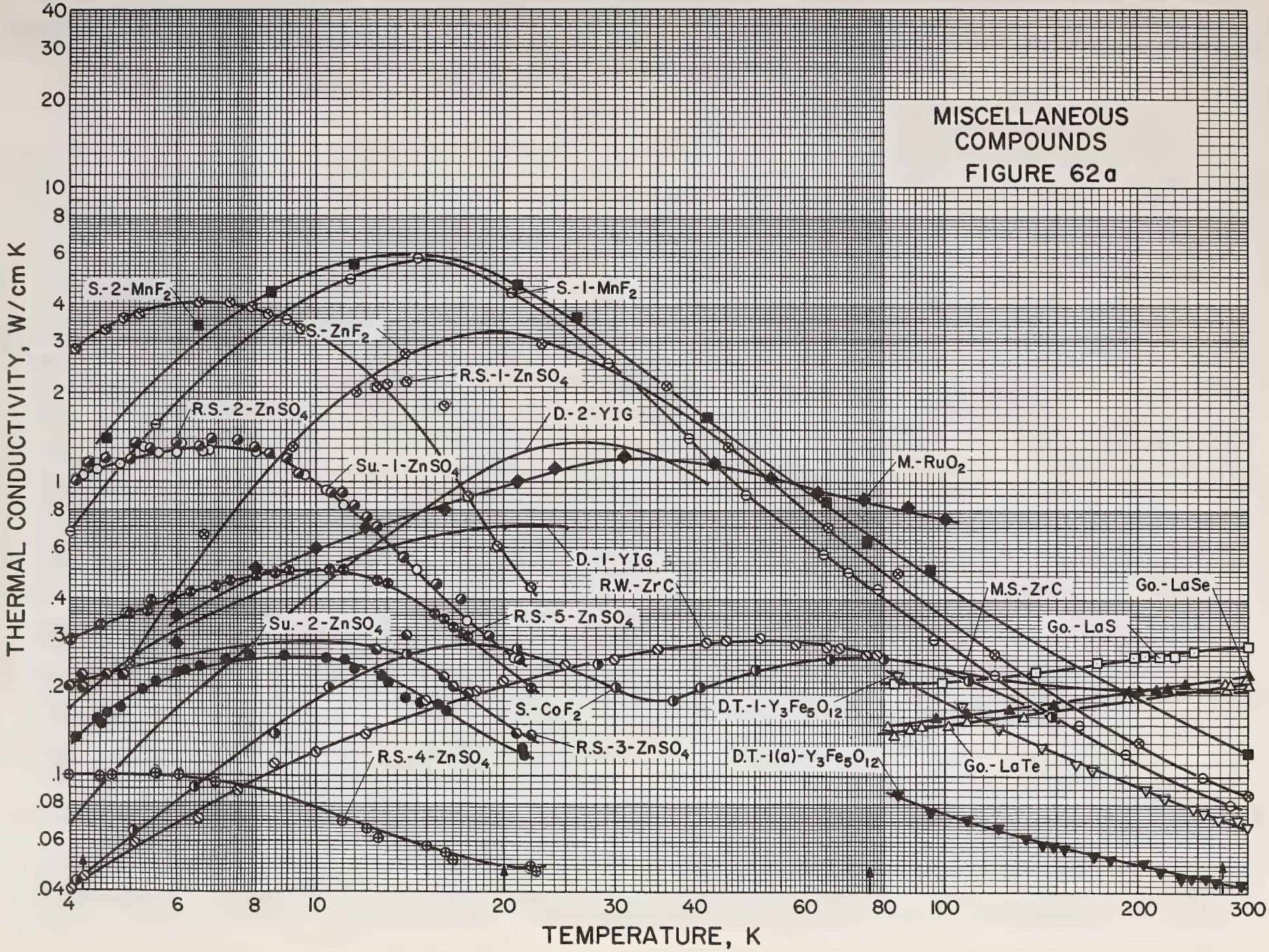
(See FIGURE 62b)

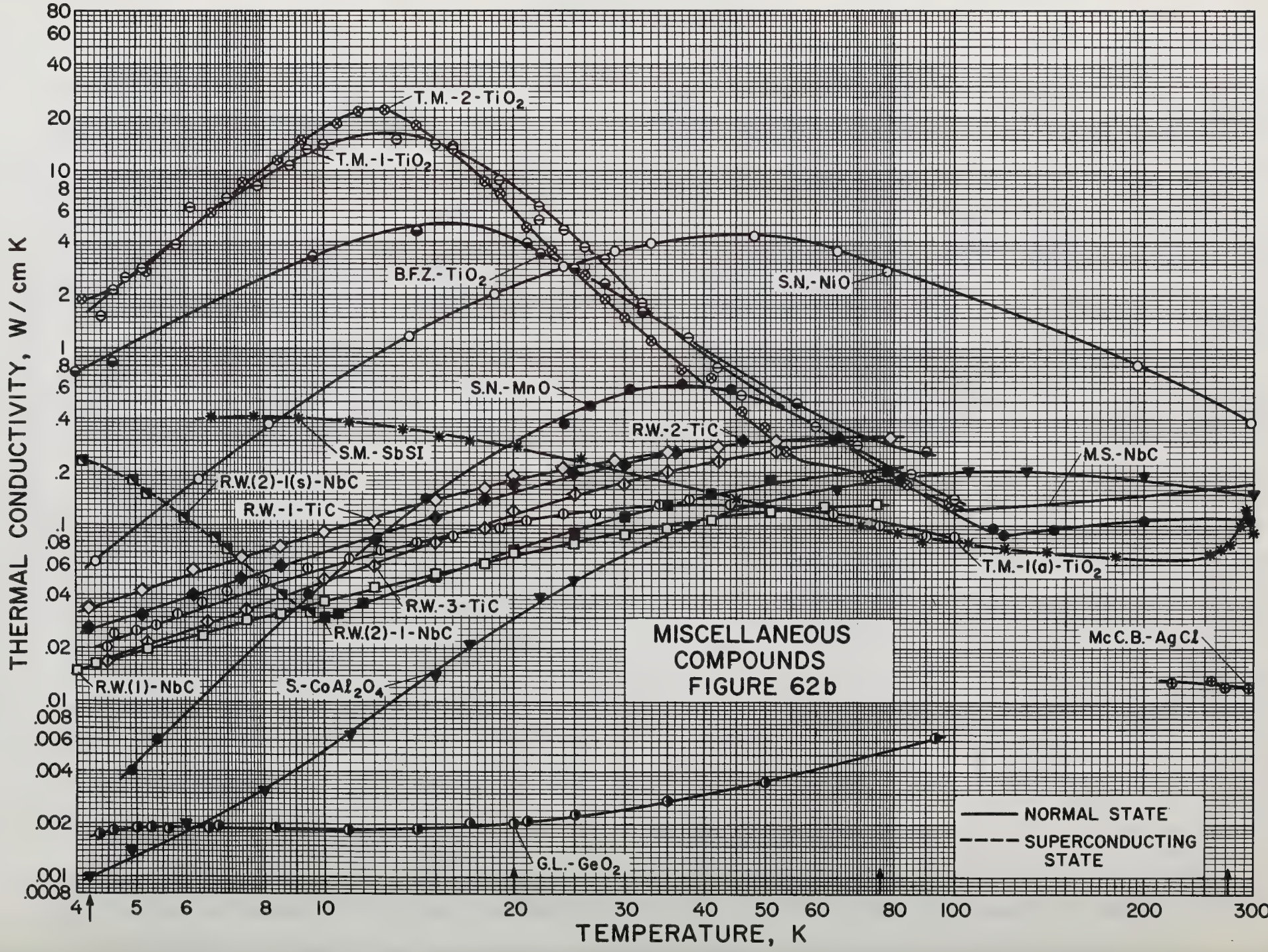
CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
G. L. -GeO_2	Compagnie Saint-Gobain; 99.9999-99.99999 pure.	Melted in platinum crucible at 1550°C; cooled rapidly to 600°C, held 15 min; cooled in 12 hrs to room temperature. Density of 3.650 g/cm^3.	A-1; B-1; C-1; D-1, 3(2); E-3; F-4; G-2; P-5, 7.	K. Guckelsberger and J. -C. Lasjaunias (1970).

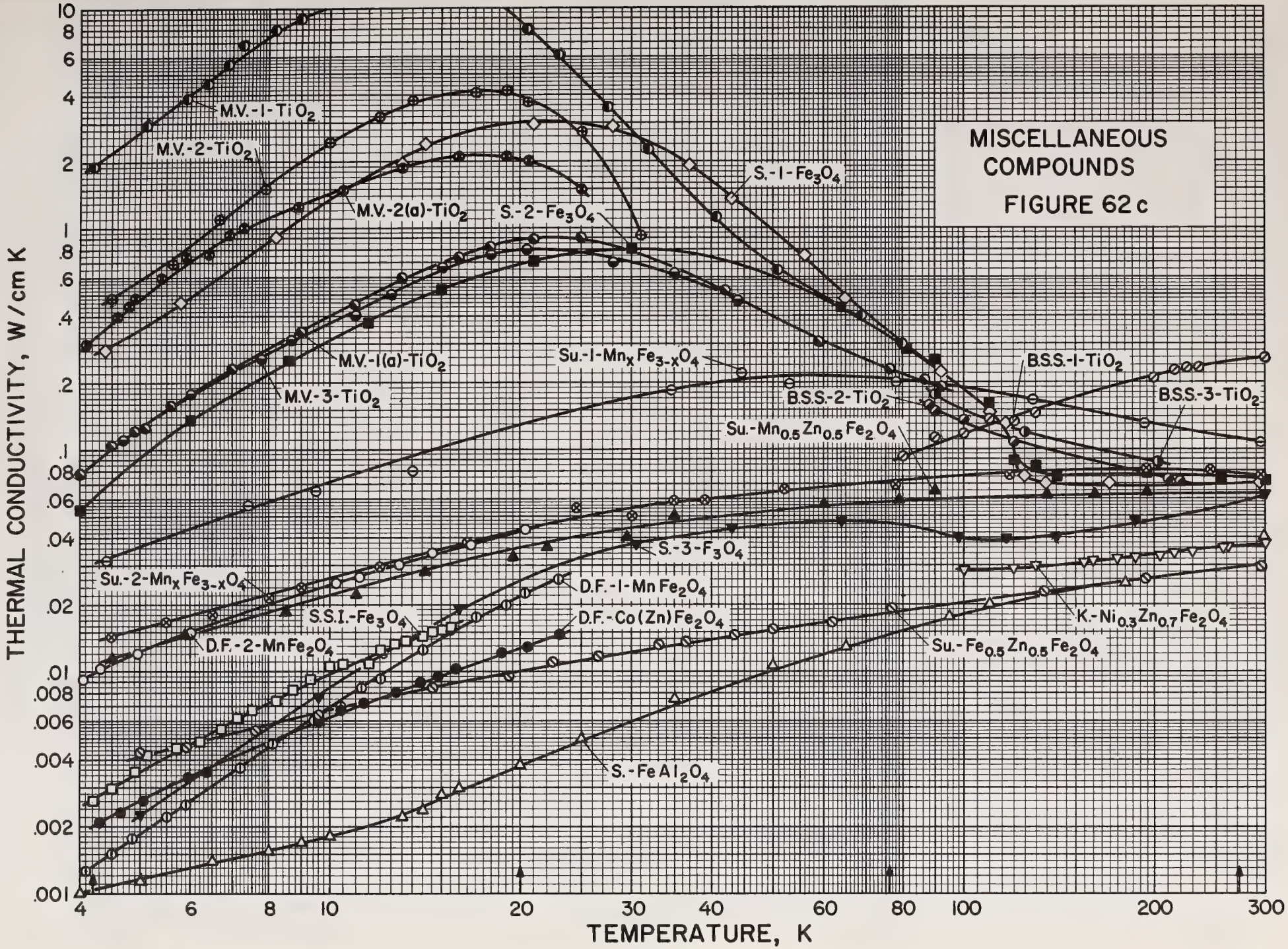
ANTIMONY IONIC CRYSTAL

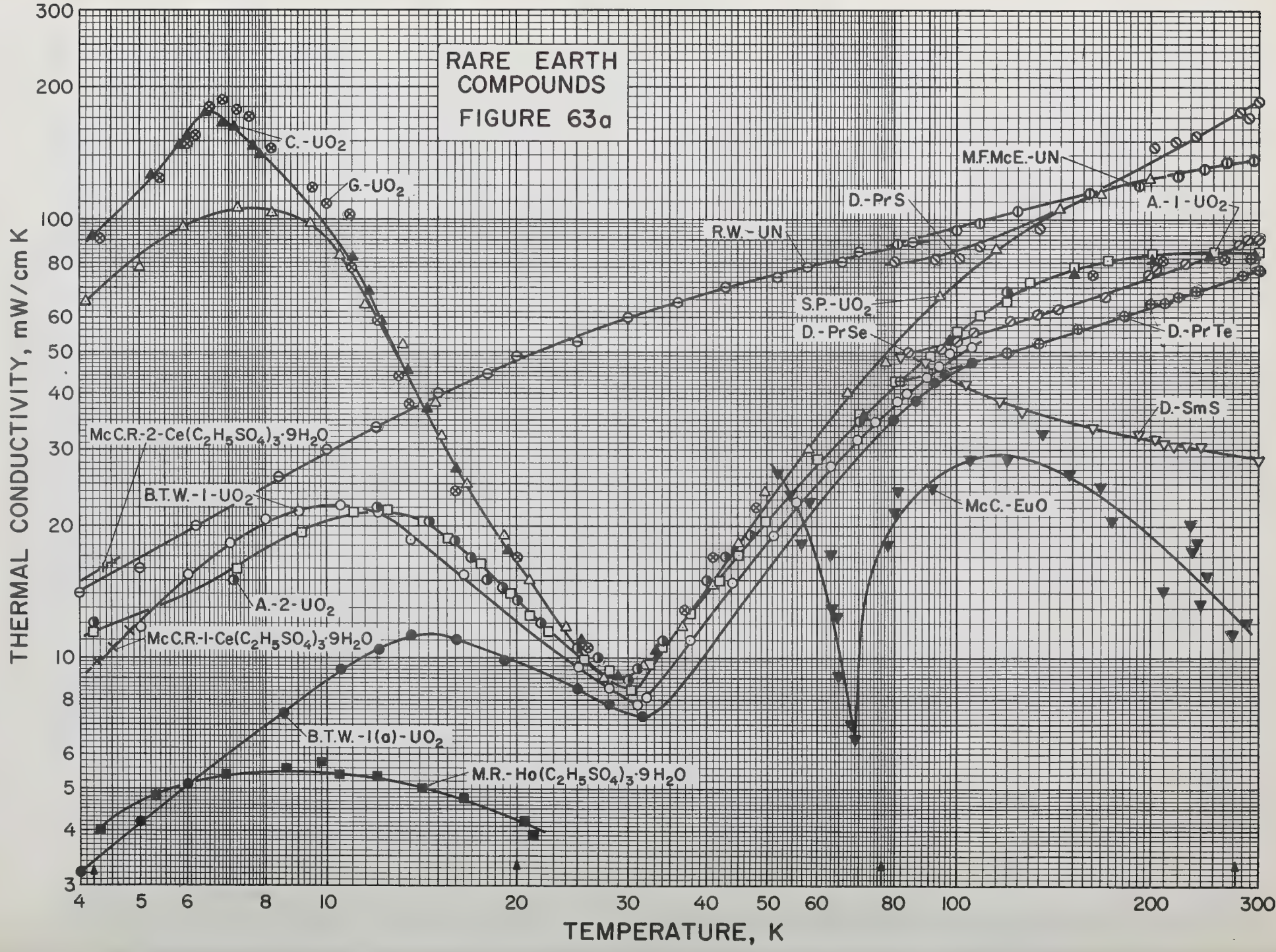
(See FIGURE 62b)

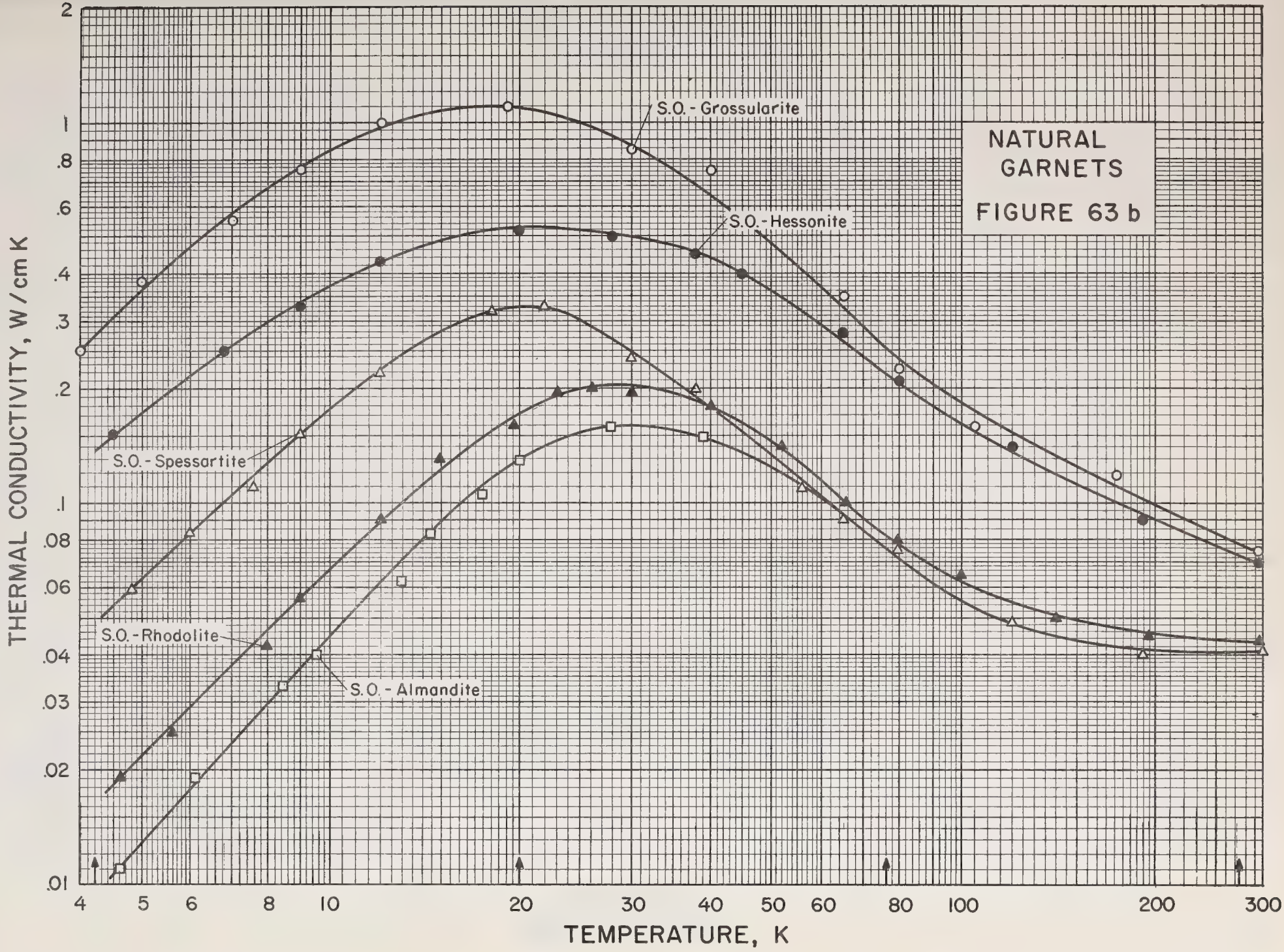
CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
S.M. -SbSI	RCA.	Single crystal; grown by sublimation; rod axis parallel to c-axis; transition temperature of 292 K; ferroelectric below 292 K, paraelectric above 292 K. Also measured specimen in electric field of 3 kV/cm parallel to heat flow at 297 K, increasing thermal conductivity by 19%.	A-1; B-1; C-1; D-1(2); E-2, 4; F-4; G-3.	E. F. Steigmeier and W. J. Merz (1968).


MISCELLANEOUS
COMPOUNDS
FIGURE 62a
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
S.-2-MnF2
S.-1-MnF2
S.-ZnF2
R.S.-1-ZnSO4
R.S.-2-ZnSO4
D.-2-YIG
Su.-1-ZnSO4
M.-RuO2
D.-1-YIG
R.W.-ZrC
M.S.-ZrC
Go.-LaSe
Go.-LaS
R.S.-5-ZnSO4
Su.-2-ZnSO4
S.-CoF2
D.T.-1-Y3Fe5O12
R.S.-3-ZnSO4
R.S.-4-ZnSO4
D.T.-1(a)-Y3Fe5O12
Go.-LaTe


THERMAL CONDUCTIVITY, W / cm K
TEMPERATURE, K
T.M.-2-TiO2
T.M.-1-TiO2
B.F.Z.-TiO2
S.N.-NiO
S.N.-MnO
S.M.-SbSI
R.W.-2-TiC
M.S.-NbC
R.W.(2)-1(s)-NbC
R.W.-1-TiC
T.M.-1(a)-TiO2
R.W.-3-TiC
R.W.(2)-1-NbC
McC.B.-AgCl
R.W.(1)-NbC
S.-CoAl2O4
G.L.-GeO2
MISCELLANEOUS COMPOUNDS FIGURE 62b
NORMAL STATE
SUPERCONDUCTING STATE


MISCELLANEOUS COMPOUNDS
FIGURE 62 c
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
M.V.-1-TiO2
M.V.-2-TiO2
M.V.-2(a)-TiO2
M.V.-1(a)-TiO2
M.V.-3-TiO2
S.-1-Fe3O4
S.-2-Fe3O4
S.-3-F3O4
Su.-1-MnxFe3-xO4
Su.-2-MnxFe3-xO4
Su.-Mn0.5Zn0.5Fe2O4
B.S.S.-1-TiO2
B.S.S.-2-TiO2
B.S.S.-3-TiO2
S.S.I.-Fe3O4
D.F.-1-MnFe2O4
D.F.-2-MnFe2O4
D.F.-Co(Zn)Fe2O4
K.-Ni0.3Zn0.7Fe2O4
Su.-Fe0.5Zn0.5Fe2O4
S.-FeAl2O4


RARE EARTH COMPOUNDS
FIGURE 63a
THERMAL CONDUCTIVITY, mW/cm K
TEMPERATURE, K
300
200
100
80
60
50
40
30
20
10
8
6
5
4
3
4
5
6
8
10
20
30
40
50
60
80
100
200
300
C.-UO2
G.-UO2
M.F.McE.-UN
A.-I-UO2
D.-PrS
R.W.-UN
S.P.-UO2
D.-PrSe
D.-PrTe
D.-SmS
McC.R.-2-Ce(C2H5SO4)3·9H2O
B.T.W.-I-UO2
McC.-EuO
A.-2-UO2
McC.R.-I-Ce(C2H5SO4)3·9H2O
B.T.W.-I(a)-UO2
M.R.-Ho(C2H5SO4)3·9H2O


NATURAL
GARNETS
FIGURE 63 b
S.O. - Grossularite
S.O. - Hessonite
S.O. - Spessartite
S.O. - Rhodolite
S.O. - Almandite
THERMAL CONDUCTIVITY, W / cm K
TEMPERATURE, K
2
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
.01
4
5
6
8
10
20
30
40
50
60
80
100
200
300

CERIUM COMPOUNDS

(See FIGURE 63a)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
McC. R. -1, 2- $Ce(C_2H_5SO_4)_3 \cdot 9H_2O$	. . . . .	Cerium ethylsulphate. #1: rod axis parallel to hexagonal axis. #2: rod axis perpendicular to hexagonal axis. Relative change in thermal conductivity in magnetic fields up to 5 T also measured.	O-9; P-5.	P. V. E. McClintock and H. M. Rosenberg (1965).

PRASEODYMIUM COMPOUNDS

(See FIGURE 63a)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
D. -PrS, PrSe, PrTe	Starting materials: praseodymium, 0.5 La, 0.04 Cu, 0.03 Fe, 0.01 Ca; grade V-5 sulfur; high-purity selenium; zone-melted tellurium.	Prepared by briquetting powders under 8000 kg/cm^2; subsequently annealed in vacuum or inert atmosphere 1-2 hrs at 1600-1800°C. PrS: praseodymium sulfide; golden-yellow color. PrSe: praseodymium selenide; reddish color. PrTe: praseodymium telluride; violet-blue color. NaCl structure. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-1(2); E-1; F-4; G-3; L-1; M-1; O-3; Q-1; S-1, 2, 5.	E. D. Devyatkova, V. P. Zhuze, A. V. Golubkov, V. M. Sergeeva, and I. A. Smirnov (1964).

SAMARIUM COMPOUNDS
(See FIGURE 63a)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
D. -SmS	Starting materials: samarium, 0.5 Eu, 0.18 Ca, 0.02 Gd, 0.01 Nd and Y; grade V-5 sulfur.	Samarium sulfide; prepared by briquetting powders under 8000 kg/cm^2; subsequently annealed in vacuum or inert atmosphere 1-2 hrs at 1600-1800°C. NaCℓ structure. Graph of lattice thermal conductivity.	A-1; B-1; C-1; D-1(2); E-1; F-4; G-3; L-1; M-1; O-3; Q-1; S-1, 2, 5.	E. D. Devyatkova, V. P. Zhuze, A. V. Golubkov, V. M. Sergeeva, and I. A. Smirnov (1964).

EUROPIUM COMPOUND

(See FIGURE 63a)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
M.C.-EuO	Semi-Elements; >90 EuO, balance Eu_2O_3.	Hot-pressed. Two runs made. Ferromagnetic below 69 K, paramagnetic above. NaCℓ structure.	A-1; B-1; C-1; D-1(3); E-2, 3; F-4; G-3; O-3; P-10; Q-5.	R.G. Morris and J. L. Cason (1968).

HOLMIUM COMPOUNDS

(See FIGURE 63a)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
M.R. - $Ho(C_2H_5SO_4)_3 \cdot 9H_2O$	. . . . .	Holmium ethylsulfate. Measured in magnetic field up to 2 T, parallel and perpendicular to hexagonal axis. Paramagnetic.	O-9; Q-5.	I. P. Morton and H. M. Rosenberg (1962).
. . . . .	. . . . .	Measured thermal conductivity of one holmium-aluminum and one - gallium single crystal garnet between 3 and 300 K.	. . . . .	G. A. Slack and D. W. Oliver (1971).

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CURVE	SAMPLE SOURCE AND ANALYSIS	REMARKS	CODE	REFERENCE
		GADOLINIUM		
. . . . .	. . . . .	Measured thermal conductivity of a gadolinium-aluminum single crystal garnet between 3 and 300 K.	. . . . .	G. A. Slack and D. W. Oliver (1971).
		TERBIUM		
. . . . .	. . . . .	Measured thermal conductivity of two terbium-aluminum and three - gallium single-crystal garnets between 3 and 300 K.	. . . . .	G. A. Slack and D. W. Oliver (1971).
		DYSPROSIUM		
. . . . .	. . . . .	Measured thermal conductivity of two dysprosium-aluminum single-crystal garnets between 3 and 300 K.	. . . . .	G.A. Slack and D. W. Oliver (1971).
		ERBIUM		
. . . . .	. . . . .	Measured thermal conductivity of one erbium-aluminum and one - gallium single-crystal garnet between 3 and 300 K.	. . . . .	G. A. Slack and D. W. Oliver (1971).
		THULIUM		
. . . . .	. . . . .	Measured thermal conductivity of one thulium-aluminum and one - gallium single-crystal garnet between 3 and 300 K.	. . . . .	G. A. Slack and D. W. Oliver (1971).
		LUTETIUM		
. . . . .	. . . . .	Measured thermal conductivity of two lutetium-aluminum single-crystal garnets between 3 and 300 K.	. . . . .	G. A. Slack and D. W. Oliver (1971).

URANIUM COMPOUNDS
(See FIGURE 63a)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
B. T. W. -1, 1(a)-UO_2	Natural UO_2.	Natural sintered UO_2. Antiferromagnetic below 30 K, paramagnetic above. #1: unirradiated. #1(a): neutron irradiated at dose of 8.6×10^{15} thermal neutrons/cm^2. Specimen also measured with lower irradiation, with intermediate results.	O-3, 5; P-2, 4, 10, 13; Q-5.	O. Bethoux, P. Thomas, and L. Weil (1963).
S. P. -UO_2	General Electric Co.	Single crystal. Antiferromagnetic below 30 K, paramagnetic above.	A-1; B-1; C-1; D-1(2); E-4, 8; F-4; G-3; O-3; P-5, 10; Q-5.	A. J. Sievers and R. O. Pohl (1964).
A. -UO_2	. . . . .	Vapor-grown single crystal; slightly oxidized.	A-6; B-1; C-1; D-1(2); F-4; G-3.	S. Amelinckx (1965).
G. -UO_2	UO_2; O/U ratio of 2.001.	Single crystal; prepared by slip casting; well-reduced. Oxidized specimen gave results very close to B. T. W. -1-UO_2.	O-5.	R. Gevers(1965).
. . . . .	UC: 0.005(weight)O_2. US: 0.3 O_2. UP: 0.13 O_2, 0.09 N_2.	UC: uranium monocarbide; prepared by arc-melting; k = 236 mW/cm-K at room temperature, calculated from thermal diffusivity measurements; corrected to theoretical density; 99% theoretical density. US: uranium monosulfide; 93% theoretical density; prepared by cold-pressing and sintering at 1800°C; k = 82 mW/cm-K. UP: uranium monophosphide; prepared by hot-pressing; 93% theoretical density; 1% second-phase; k = 125 m W/cm-K at room temperature. Graph of electronic thermal conductivity.	L-1; M-1; O-1; P-2, 5.	J. B. Moser and O. L. Kruger (1967).
R. W. -UN	Same specimen as M. F. McE. below.	Transition temperature of 53 K. Graph of electronic and lattice thermal conductivity.	L-1; M-1; O-1; P-2, 5, 10; Q-1.	L. G. Radosevich and W. S. Williams (1969).

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URANIUM COMPOUNDS (cont'd)

(See FIGURE 63a)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
M. F. McE. -UN	<1 (volume) UO_2; RRR(25) = 24.9.	Pressed, sintered nitrogen for 3/4 hr at 2600 K; annealed 8.5 hrs at 2500 K; density of 13.6 g/cm^3, 97% theoretical. Grain size of 40μ; microhardness 659 mm^2/kg (DPH) at 25 gm-load. Data corrected to theoretical density. Graph of electronic and lattice thermal conductivity.	A-1; B-1; C-1; D-1(2); E-2; F-1; G-3; L-1; M-1, 6; O-1, 3; S-1, 2.	J. P. Moore, W. Fulkerson, and D. L. McElroy (1970).

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MINERALS
(See FIGURE 63b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	#1: sylvite. #2: rock salt. #3: topaz. #4: zincblend. #5: beryll. #6: tourmaline.	#1(a): natural crystal; k = 0.159 at 83 K; k = 0.075 at 273 K. #1(b): pressed at 8,000 atm; k = 0.343 at 83 K; k = 0.084 at 273 K. #2: pressed at 8,000 atm; k = 0.180 at 83 K; k = 0.063 at 273 K. #3: k = 0.234 at 273 K. #4: k = 0.063 at 83 K; k = 0.264 at 273 K. #5: k = 0.088 at 83 K; k = 0.084 at 273 K. #6: k = 0.038 at 83 K; k = 0.046 at 273 K.	. . . . .	A. Eucken and G. Kuhn (1928).
S.O. -Grossularite, -Hessonite, -Spessartite, -Rhodolite, -Almandite	Composition of form $R_3Al_2Si_3O_{12}$ with fractions of R as Fe^{2+} and Mn^{2+} as follows: "G"-0.03, 0.[illegible]"H"-0.07, —; "S"-0.02, 0.21; "R"-0.56, —; "A"-0.49, 0.02. "G" and "H" contain calcium as 0.96 and 0.93 fraction of R. "S", "R", and "A" contain magnesium as 0.67, 0.44, 0.49 fraction of R.	Natural single crystals.	A-1; B-1; C-1; D-1(2); E-1, 4; F-4; G-3; O-3, 9; P-2, 5, 7.	G. A. Slack and D. W. Oliver (1971).

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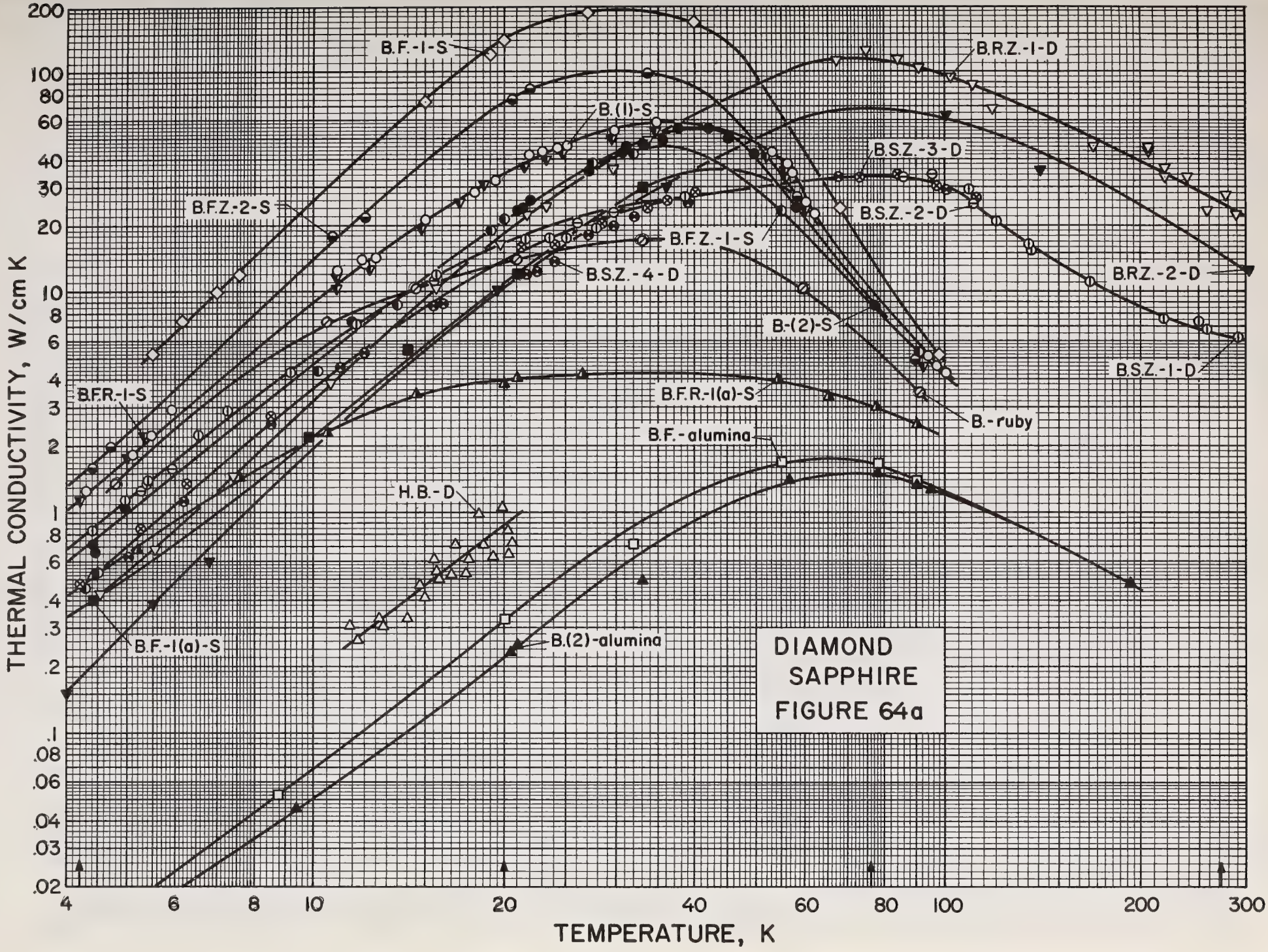
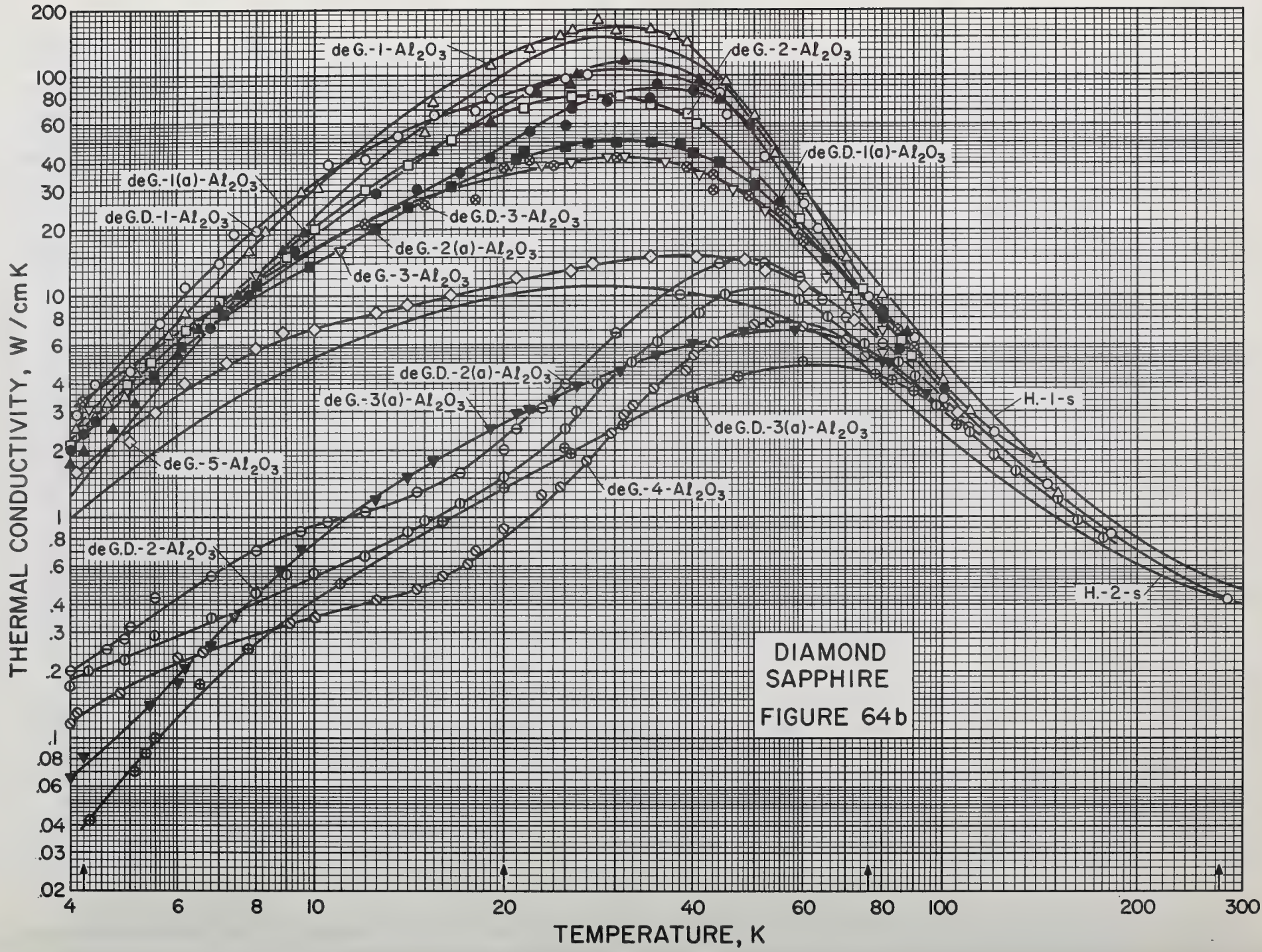
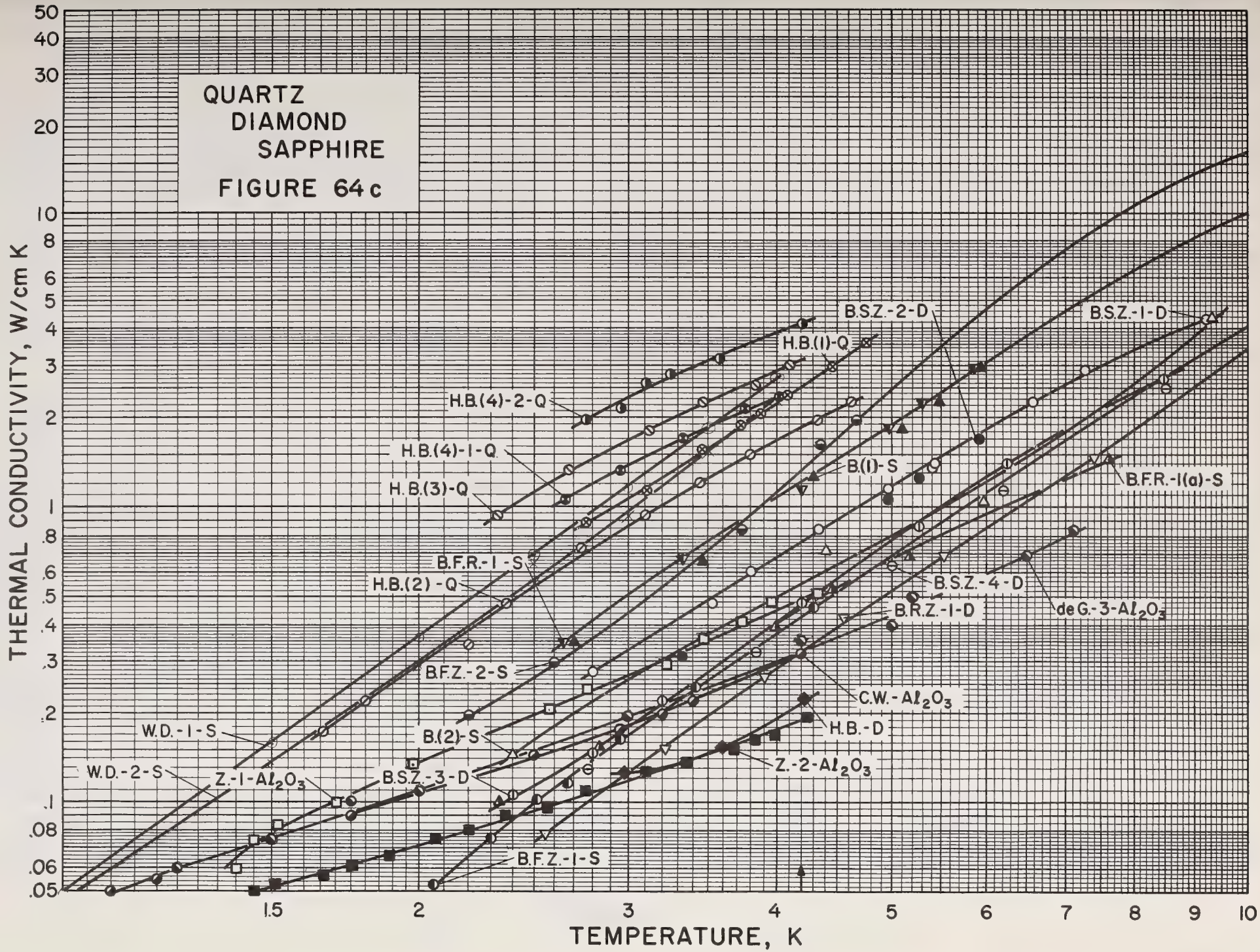

THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
200
100
80
60
40
30
20
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
4
6
8
10
20
40
60
80
100
200
300
B.F.-1-S
B.R.Z.-1-D
B.(1)-S
B.S.Z.-3-D
B.F.Z.-2-S
B.S.Z.-2-D
B.F.Z.-1-S
B.S.Z.-4-D
B.R.Z.-2-D
B.-(2)-S
B.S.Z.-1-D
B.F.R.-1-S
B.F.R.-1(a)-S
B.-ruby
B.F.-alumina
H.B.-D
B.F.-1(a)-S
B.(2)-alumina
DIAMOND
SAPPHIRE
FIGURE 64a


THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
deG.-1-Al2O3
deG.-2-Al2O3
deG.D.-1(a)-Al2O3
deG.-1(a)-Al2O3
deG.D.-1-Al2O3
deG.D.-3-Al2O3
deG.-2(a)-Al2O3
deG.-3-Al2O3
deG.D.-2(a)-Al2O3
deG.-3(a)-Al2O3
deG.D.-3(a)-Al2O3
deG.-5-Al2O3
deG.-4-Al2O3
deG.D.-2-Al2O3
H.-1-s
H.-2-s
DIAMOND
SAPPHIRE
FIGURE 64b


QUARTZ
DIAMOND
SAPPHIRE
FIGURE 64c
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
50
40
30
20
10
8
6
5
4
3
2
1
.8
.6
.5
.4
.3
.2
.1
.08
.06
.05
1.5
2
3
4
5
6
7
8
9
10
B.S.Z.-2-D
B.S.Z.-1-D
H.B.(1)-Q
H.B.(4)-2-Q
H.B.(4)-1-Q
H.B.(3)-Q
B.(1)-S
B.F.R.-1(a)-S
B.F.R.-1-S
H.B.(2)-Q
B.S.Z.-4-D
B.R.Z.-1-D
deG.-3-Al2O3
B.F.Z.-2-S
C.W.-Al2O3
H.B.-D
W.D.-1-S
B.(2)-S
W.D.-2-S
Z.-1-Al2O3
B.S.Z.-3-D
Z.-2-Al2O3
B.F.Z.-1-S

DIAMOND

(See FIGURES 64a-64c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
H. B. -D	I. J. Asscher.	Also measured k = 14.3 at 89 K.	A-1; B-1; C-1; D-2(2); E-2, 5; F-4; G-2.	W. J. deHaas and T. Biermasz (1938a).
B. S. Z. -1, 2, 3, 4-D	Type I stone.	Measured the "size effect" of diamond crystals with square cross-section; 10.9 mm overall length. #1: 3.9 mm wide, 6.8 mm long. #2: 3.1 mm wide. #3: 1.7 mm wide. #4: 1.1 mm wide, 6.9 mm long.	A-1; B-1; C-1; D-2, 4(2); E-4; F-4; G-2; O-3; P-3, 5.	R. Berman, F. E. Simon, and J. M. Ziman (1953).
B. F. Z. -1, 2-D	#1: type IIa. #2: type IIb.	#1: 10 mm long, 0.7 x 1.25 mm cross-section; electrical insulator. #2: 7 mm long, 1.1 x 1.2 mm cross-section; electrical conductor.	A-1; B-1; C-1; D-2, 4(2); E-4; F-4; G-2; O-3; P-2, 8; Q-1.	R. Berman, E. L. Foster, and J. M. Ziman (1956).
. . . . .	. . . . .	Review of thermal conductivity of diamond. Also see SILICON DIELECTRIC CRYSTALS and FIGURE 62b.	. . . . .	G. A. Slack (1964).

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ALUMINA and SAPPHIRE (Al_2O_3) CRYSTALS

(See FIGURES 64a-64c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
B.(1)-S	Salford Electrical Instruments.	"Corundum"; artificial single crystal sapphire. Length of 6 cm, diameter of 3 mm. Rod axis inclined 36° to principal axis.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-3; O-3, 9; P-2, 5, 13, 15.	R. Berman (1951a).
B.(2)-S	Salford Electrical Instruments.	Same specimen as B.(1)-S above, except diameter of 1.5 mm.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-3; O-3, 9; P-2, 5, 13, 15.	R. Berman (1952b).
B.(2)-Alumina	. . . . .	Sintered alumina, $A\ell_2O_3$; density of 3.70 g/cm^3 (within 5% of single crystal); grain sizes 5-30μ.	Same as above.	Same as above.
B.-ruby	Corundum; Oil-1 Cr.	Artificial ruby; corundum specimen with Cr impurity.	Same as above.	Same as above.
B.F.R.-1, 1(a)-S	. . . . .	Synthetic sapphire (corundum, $A\ell_2O_3$); 7 cm long, 3 mm diameter. #1: unirradiated. #1(a): after cumulative dose of 3×10^6 R by 50.2×10^{17} fast neutrons/cm^2. Also measured with three lower doses of irradiation, with intermediate results. Another sapphire specimen also measured before and after irradiation with Co-gamma rays; results identical for 1 and 1.4 - MeV gamma irradiation, 30% less than unirradiated measurements at the maximum of the thermal conductivity.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-3; O-5; P-2, 4, 5, 13, 15.	R. Berman, E. L. Foster, and H. M. Rosenberg (1954).
B.F.Z.-1, 2-S	#1: General Electric Company Ltd. #2: Linde Air Products.	Artificial sapphire (pure $A\ell_2O_3$). #1: length of 13 mm, diameter of 1.02 mm; rod axis inclined 36° to principal axis; matt surface. #2: length of 6 cm, diameter of 2.47 mm; rod axis inclined 40-60° from principal axis; annealed at a temperature slightly below melting point; matt surface. Nine other specimens measured, some with polished surface, with similar results.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-3; O-3; P-5, 15.	R. Berman, E. L. Foster, and J. M. Ziman (1955).

ALUMINA and SAPPHIRE (Al_2O_3) CRYSTALS (cont'd)

(See FIGURES 64a-64c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
B.F.-1, 1(a)-S	. . . . .	Synthetic single crystal sapphire. #1: untreated. #1(a): stretched at 1400°C, resulting in a 15% elongation. Same specimen was γ-irradiated to total of 3×10^7 R; results identical to #1(a). Five other specimens also measured after γ irradiation and heat treatments.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-3; P-3.	R. Berman, E. L. Foster, B. Schneidmesser, and S. M. A. Tirmizi (1960).
B.F.-alumina	. . . . .	Sintered alumina. Crystallites about 20μ in size. Specimen also measured after γ-irradiation; results identical to untreated alumina.	Same as above.	Same as above.
H.-1, 2-S	Linde. #1: <0.001 Cr, Fe, Mg, and Si, <0.0001 Ag, Ca, and Cd.	Rod axis parallel to c-axis. #1: sapphire. #2: ruby.	A-1; B-1; C-1; D-1(2); E-4; F-4; G-3; O-3; P-2, 5, 12.	M. G. Holland (1962).
deG. D.-1, 1(a), 2, 2(a), 3, 3(a)-Al_2O_3	#1: pure. #2: 2200 ppm(weight) Mn. #3: doped with 890 ppm Cr.	Specimens 40 mm long, 8 mm diameter; rod axis inclined 60° to principal axis. #1: slight orange color. #1(a): irradiated at room temperature by γ-rays with total dose of 3×10^6 R. #2(a): irradiated identically to #1(a). #3: ruby; annealed at 800°C. #3(a): irradiated at room temperature by γ-rays with total dose of 9×10^7 R. Four other specimens with different irradiations and annealings also measured; #3 also measured in longitudinal magnetic field of up to 0.42 T.	D-1, 3(2); G-2; O-3, 9; P-5, 7, 13.	A. M. deGoer and B. Dreyfus (1967).
Z.-1, 2-Al_2O_3	#1: doped with 0.1(weight) MnO_2. #2: doped with 0.35 MnO_2.	Rod axis inclined 60° to the principal axis. Specimens 40 mm long x 8 mm diameter. Also measured in magnetic field of 1.18 T.	G-2; P-2, 5, 12.	F. Zadworny (1967).
deG.-1, 1(a), 2, 2(a), 3, 3(a), 4, 5-Al_2O_3	Kochlight, except #2. #2: Alpes; doped with Fe, 115 ppm (weight) Fe. #3: doped with Cr, 1050 ppm Cr. #4: doped with Mn, 60 ppm Mn. #5: doped with V, 1115 ppm V.	#1: pure; 50 mm in length, 5 mm diameter. #1(a): irradiated by γ-rays with dosage of 3×10^6 R. #2: same size as #1. #2(a): irradiated identically to #1(a). #3(a): irradiated identically to #1(a). Also measured #5 in a magnetic field of 0.4 T. Also measured 3 other specimens in unirradiated and irradiated set up.	O-3, 9; P-2, 3, 5, 7.	A. M. deGoer (1969).

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ALUMINA and SAPPHIRE (Al_2O_3) CRYSTALS (cont'd)

(See FIGURES 64a-64c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
C.W.-Al_2O_3	Same specimen as deG.-3 above.	Rod axis inclined 59° to axis and 61° to c-axis. Also measured in magnetic field up to 2.1 T normal to rod axis.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-2; P-2, 5, 7.	L. J. Challis and R. G. Ward (1970).
W.D.-1, 2-S	#1: Nuclear Elements; in ppm(weight): 15 ppm Ti, 10 S, 5 Na, 4 Cl and Si, 2 Ca and Fe, 1 K, <1 Cr and Mg. #2: Adolf Meller; in ppm(weight): 10 ppm Na, 4 Ca, Cl, Si, and Ti, 3 S, 2 K, <2 Mg, 1 Fe, <1 Cr.	Single crystals; rod axis inclined 8 to 10° from (100) crystal axis; cylinders 3.2 mm diameter x 3.18 mm long. Also measured two other specimens with intermediate conductivity. Also measured below 1 K.	G-3; O-1; P-5.	M. W. Wolfmeyer and J. R. Dillinger (1971).

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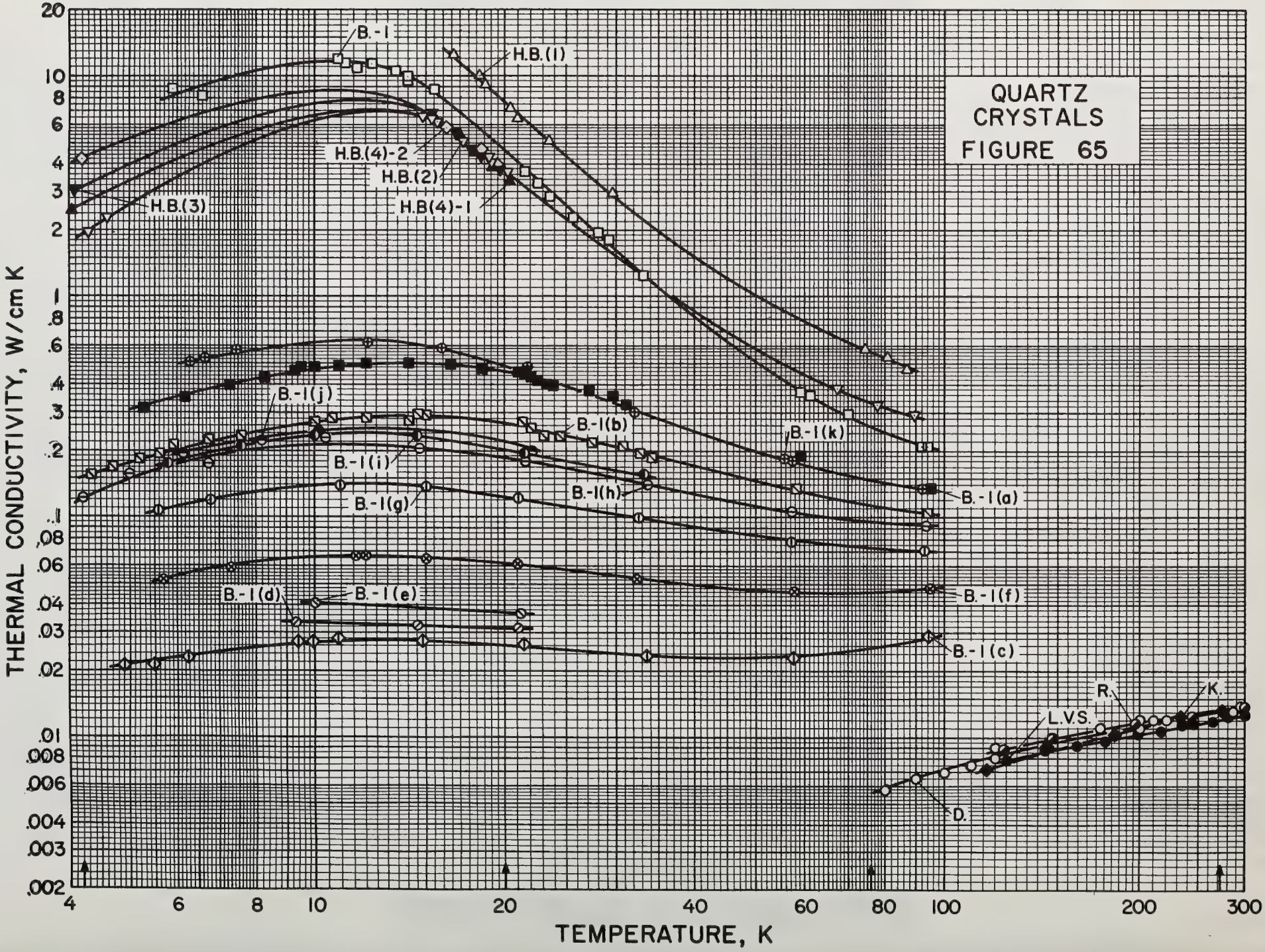
QUARTZ CRYSTALS
FIGURE 65
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
B.-1
H.B.(1)
H.B.(4)-2
H.B.(2)
H.B.(3)
H.B(4)-1
B.-1(j)
B.-1(b)
B.-1(k)
B.-1(i)
B.-1(h)
B.-1(g)
B.-1(a)
B.-1(d)
B.-1(e)
B.-1(f)
B.-1(c)
R.
K.
L.V.S.
D.
20
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
.01
.008
.006
.004
.003
.002
4
6
8
10
20
40
60
80
100
200
300

QUARTZ (SiO_2) CRYSTALS

(See FIGURES 64b and 65)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	Measured the thermal resistance of quartz between 20 and 273 K.	. . . . .	A. Eucken (1911b).
H. B. (1)	. . . . .	Single crystal. Length of 5 cm, diameter of 0.3 cm. Rod axis parallel to principal axis.	A-1; B-1; C-1; D-2(2); E-2, 5; F-4; G-3.	W. J. deHaas and T. Biermasz (1935).
H. B. (2)	. . . . .	Single crystal. Diameter of 0.216 cm, length of 3.20 cm. Rod axis perpendicular to principal axis and parallel to bisector of two binary axes.	Same as above.	W. J. deHaas and T. Biermasz (1937).
H. B. (3)	. . . . .	Same as H. B. (2) above, except diameter of 0.454 cm; length of 4.80 cm.	Same as above.	W. J. deHaas and T. Biermasz (1938a) and (1938b).
H. B. (4)-1, 2	. . . . .	#1: same specimen as H. B. (3); diameter ground down to 0.359 cm; length of 4.48 cm. #2: diameter of 0.775 cm, length of 4.40 cm.	Same as above.	W. J. deHaas and T. Biermasz (1938c).
B. -1, 1(a), 1(b), 1(c), 1(d), 1(3), 1(f), 1(g), 1(h), 1(i), 1(j), 1(k).	. . . . .	Single crystal. Length of 5 cm; square cross-section, 5 mm on a side. Rod axis perpendicular to principal axis. #1: untreated. #1(a): irradiated below 100°C in Harwell pile 1.8×10^{18} thermal neutrons/cm^2. #1(b): irradiated again 2.5×10^{18} thermal neutrons/cm^2; after measurement, heated for 3 weeks at 100°C, with no change in values. #1(c): irradiated again at 3×10^{19} thermal neutrons/cm^2. #1(d): then heated 8 hrs at 300°C. #1(e): heated again 6 hrs at 400°C. #1(f): heated again 6 hrs at 510°C. #1(g): heated again 6 hrs at 565°C. #1(h): heated again 60 hrs at 540°C. #1(i): heated again 677 hrs at 540°C. #1(j): heated again 1 hr at 600°C. #1(k): heated again 6 hrs at 700°C.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-2; O-3; P-2, 5, 13, 15.	R. Berman (1951a); see also R. Berman, P. G. Klemens, F. E. Simon, and T. M. Fry (1950).

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QUARTZ (SiO_2) CRYSTALS (cont'd)

(See FIGURES 64b and 65)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
R.	Fused quartz.	Fused quartz. Also measured a specimen of crystalline quartz with rod axis perpendicular to optical axis; k = 0.0633 W/cm-K at 28 K.	. . . . .	E. H. Ratcliffe (1959).
D.	M. V. Lomonosov.	Fused quartz; lateral surface had matte black finish; smoked in flame of benzene and paraffin.	A-1; B-1; C-1; D-1(4); F-5; G-3.	E. D. Devyamkova, A. V. Pemrov, I. A. Smirnov, and B. Ya. Moizhes (1960).
K.	. . . . .	Fused quartz.	A-6; B-2; C-1.	I. K. Kamilov (1963).
L. V. S.	. . . . .	Fused quartz. Calculated from thermal diffusivity measurements.	A-3; B-1; C-1; D-1; F-4.	A. V. Luikov, L. L. Vasiliev, and A. G. Shashkov (1965).

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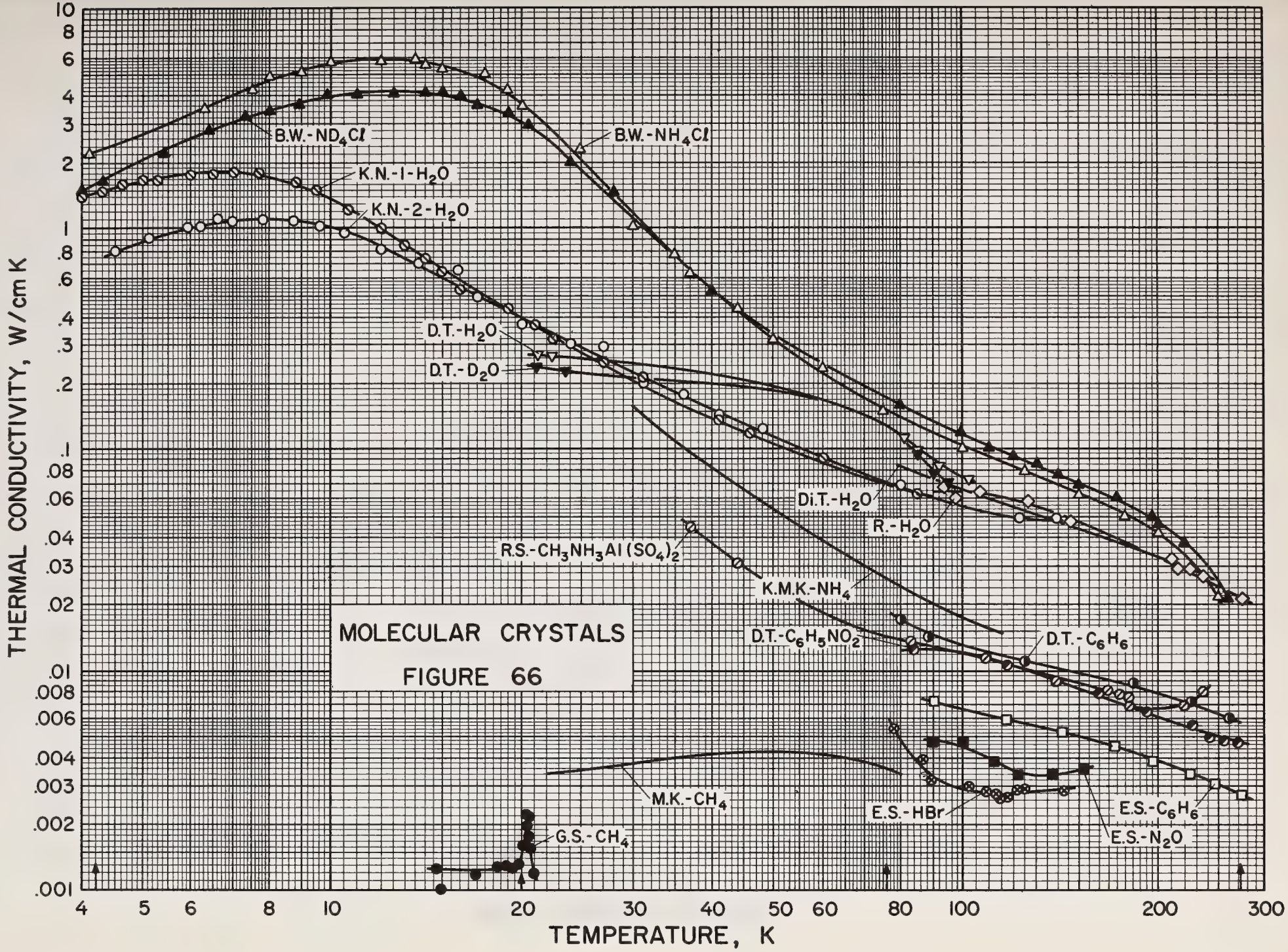
3.5. MOLECULAR CRYSTALS


THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
.01
.008
.006
.004
.003
.002
.001
4
5
6
8
10
20
30
40
50
60
80
100
200
300
B.W.-ND4Cl
B.W.-NH4Cl
K.N.-1-H2O
K.N.-2-H2O
D.T.-H2O
D.T.-D2O
Di.T.-H2O
R.-H2O
R.S.-CH3NH3Al(SO4)2
K.M.K.-NH4
D.T.-C6H5NO2
D.T.-C6H6
M.K.-CH4
G.S.-CH4
E.S.-HBr
E.S.-C6H6
E.S.-N2O
MOLECULAR CRYSTALS
FIGURE 66

WATER MOLECULAR CRYSTALS

(See FIGURE 66)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Distilled H_2O.	Results differ considerably from all later measurements.	. . . . .	C.H. Lees (1905).
. . . . .	#1: H_2O. #2: D_2O.	Slowly cooled. #1: k = 0.0216 at 262 K; k = 0.0057 at 271 K. #2: k = 0.0215 at 264 K; k = 0.0055 at 273 K.	A-7; B-4; C-1; D-1(4); G-3.	R.W. Powell (1958).
R. -H_2O	Distilled H_2O.	Prepared by slow cooling from boiled H_2O; fairly clear, containing some trapped air.	A-1; B-2; C-1; D-1(6); F-3; G-3; O-3.	E.H. Ratcliffe (1962).
D. T. -H_2O,D_2O	H_2O; deaerated-distilled. D_2O: deaerated-distilled 99.9 pure.	Cooled slowly.	A-1; B-2; C-2; D-1(2); E-5; F-4; G-3; O-3.	J.W. Dean and K. D. Timmerhaus (1962).
Di. T. -H_2O	Pure reagent grade, deaerated.	Boiled several hours slowly, then boiled 5-10 min vigorously; 6 or more hours to freeze.	A-1; B-2; C-1; D-1(8); E-2; F-4; G-3.	D.S. Dillard and K. D. Timmerhaus (1969).
K. N. -1,2-H_2O	. . . . .	Single crystals; 7-8 cm diameter, 20 cm long; rod axis parallel to optical axis.	A-1; B-1; C-1; D-1(2); G-2; O-3.	J. Klinger and K. Neumaier (1969).

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AMMONIUM IONIC and MOLECULAR CRYSTALS

(See FIGURE 66)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	#1: NH_4Cl. #2: NH_4Br.	#1: k = 0.109 at 83 K; k = 0.025 at 273 K. #2: k = 0.067 at 83 K; k = 0.025 at 273 K.	. . . . .	A. Eucken and G. Kuhn (1928).
. . . . .	. . . . .	Measured the thermal resistance of NH_4Cl; observed λ-discontinuity at transition temperature of 242 K.	. . . . .	C. V. Simson (1951).
K. M. K. -NH_4	≥ 99.99 pure.	Grown from liquid at rate of 5 mm/hr; annealed some hours close to triple point; fully transparent; cooled slowly at rate of 10°C/hr. Two other specimens grown from vapor phase gave identical results.	A-1; B-1; C-1; D-1(2); E-2; F-2; G-2; O-3, 5, 9.	I. N. Krupskii, V. G. Manzhely, and L. A. Koloskova (1968); see also (1966).
B. W. -NH_4Cl, ND_4Cl	Urea added.	Grown from solution by slow cooling or isothermal evaporation; cubic crystal habit. Discontinuity and hysteresis between 242.23 and 242.59 K for NH_4Cl. NH_4Cl: k = 1.4 at 3 K; k = 0.68 at 2 Kl k = 0.35 at 1.5 K. ND_4Cl: k = 0.79 at 3 K; k = 0.40 at 2 K; k = 0.20 at 1.5 K.	A-1; B-1; C-1; D-1(2); G-3; O-3; P-2, 3, 5, 7.	W. Bausch and W. Waidelich (1969).
R. S. - $CH_3NH_3Al(SO_4)_2$	$CH_3NH_3Al(SO_4)_2 \cdot 12H_2O$.	Methylammonium aluminum alum; single crystal; rod axis parallel to [100] axis; transition temperature at 176 K; orthorhombic ferroelectric below 176 K, cubic paraelectric above; specimen size of 7 x 7 x 7 mm.	A-1; B-2; C-1; G-3; O-3; P-2, 7.	M. Rechowicz and H. Steeple (1970).

MISCELLANEOUS MOLECULAR CRYSTALS

(See FIGURE 66)

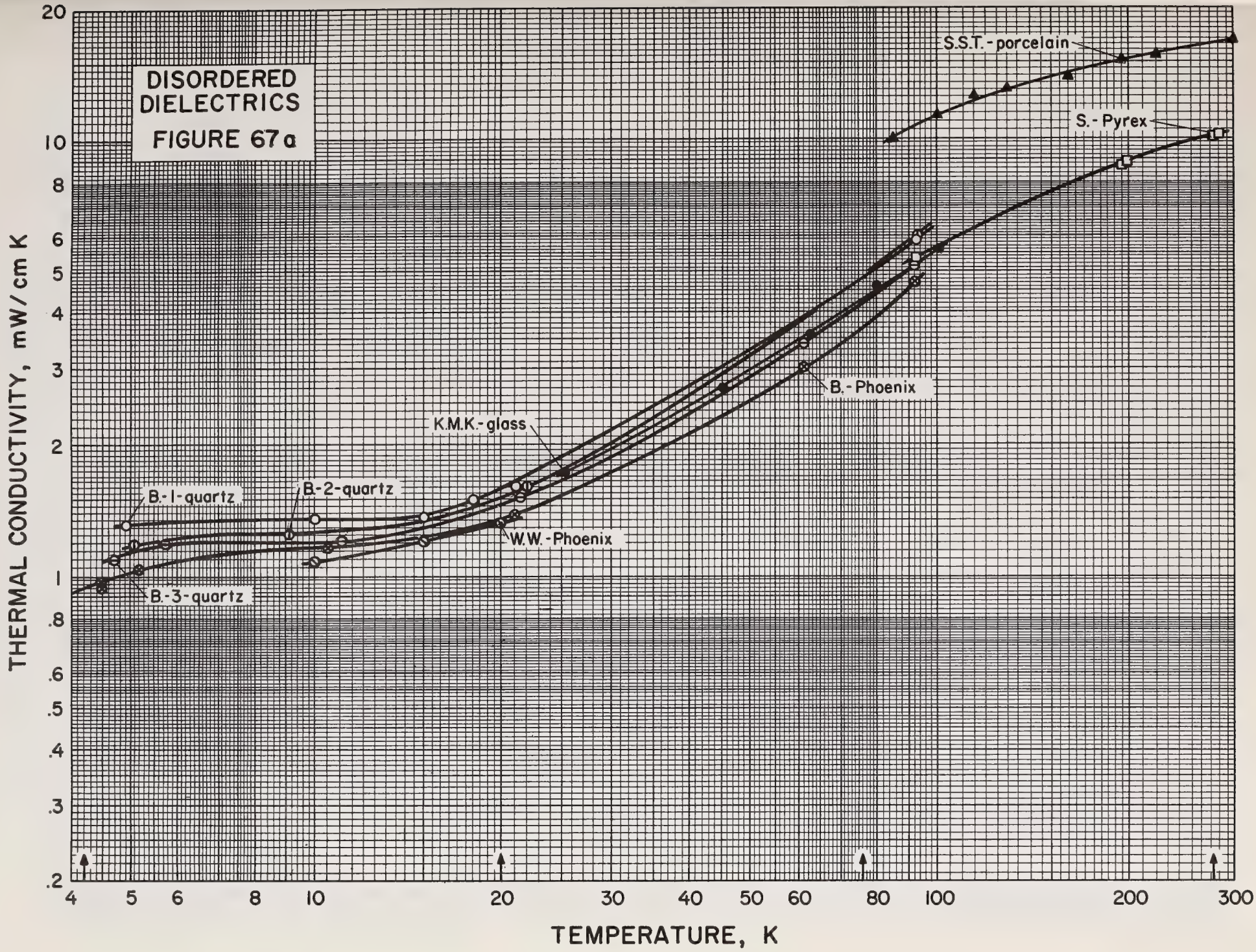
CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	#1: paraffin.	#1: slowly cooled from underneath; melting point of 54°C; k = 0.0026 at 115 K; k = 0.00256 at 237 K; k = 0.0024 at 283 K.	A-1; B-1; C-1; D-2(2); E-2; F-4; G-3.	C. H. Lees (1905).
	#2: naphtha line ($C_{10}H_8$).	#2: slowly cooled from underneath; melting point of 79°C; k = 0.0054 at 118 K; k = 0.0041 at 213 K; k = 0.0030 at 331 K.		
	#3: naphthol (naphthalene-2-hydroxy; β-naphthal; $C_{10}H_8O$).	#3: heated in an oil bath, cooled; k = 0.0029 at 104 K; k = 0.0026 at 214 K; k = 0.0025 at 317 K.		
	#4: glycerine ($HOCH_2CHOHCH_2OH$).	#4: frozen from below with liquid air; k = 0.0032 at 101 K; k = 0.0034 at 202 K; k = 0.0030 at 292 K.		
	#5: aniline ($C_6H_5NH_2$).	#5: frozen from below; slight orange color; k = 0.0056 at 92 K; k = 0.0032 at 198 K; k = 0.0029 at 234 K.		
	#6: diphenylamine ($C_6H_5NHC_6H_5$).	#6: melted crystals over water bath; frozen slowly from beneath; melting point of 54°C; k = 0.0025 at 91 K; k = 0.0023 at 200 K; k = 0.0022 at 299 K.		
	#7: 4-nitropheno ($C_6H_5NO_3$).	#7: melting point of 114°C; k = 0.0047 at 95 K; k = 0.0032 at 203 K; k = 0.0027 at 280 K.		
E.S.-C_6H_6, HBr, N_2O	. . . . .	C_6H_6: benzene; slowly crystallized; transparent; rod axis perpendicular to principal axis. HBr: prepared from hydro-bromic acid; transitions at 89 and 113 K. NO_2: purified by distillation.	A-1; B-1; C-1; D-2(2); F-4; G-3.	A. Eucken and E. Schröder (1939).
G.S.-CH_4	Technically pure; purified by multiple distillation.	Slowly solidified at 63 K. Transparent, but not completely clean; holes. Transition at 20.4 K.	A-1; B-1; C-1; D-2(2); F-4; G-3; P-7.	A. N. Gerritsen and P. van der Star (1942).
. . . . .	CH_4	Thermal conductivity of a probably solid specimen was measured during runs on the gas at high pressures.	. . . . .	L. D. Ikenberry and S. A. Rice (1963).

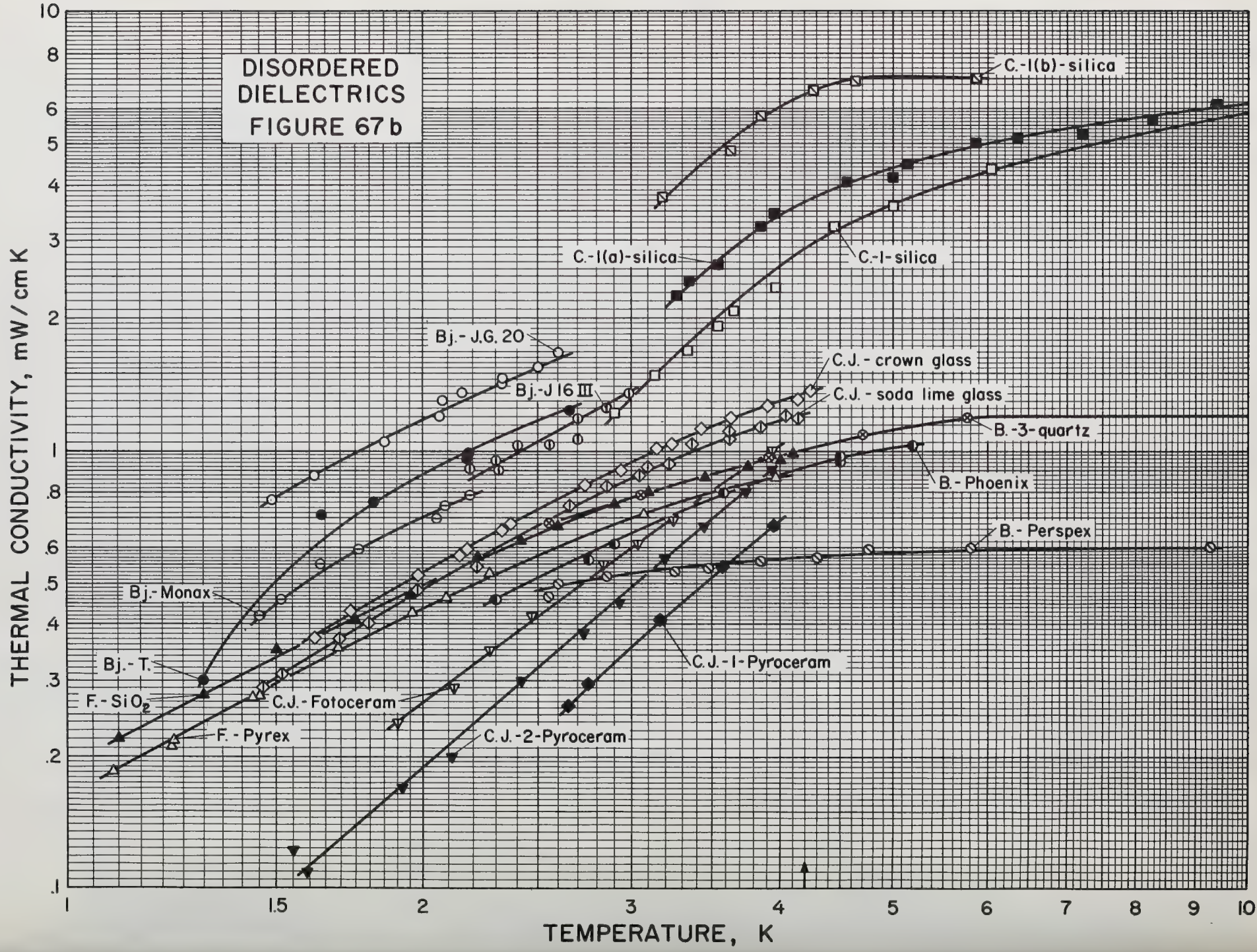
MISCELLANEOUS MOLECULAR CRYSTALS (cont'd)

(See FIGURE 66)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
M. K. -CH_4	99.99 gas purity.	Grown from vapor phase; transparent; no visible defects. Diameter of 1.85 cm, length of 5 cm. Smoothed values of single crystal and two polycrystal specimens measured; results same within limits of experimental error.	A-1; B-1; C-1; D-1(2); E-2; F-2; G-3; P-7.	V. G. Manzhelii and I. N. Krupskii (1968).
D. T. -C_6H_6, $C_6H_5NO_2$	Pure reagent grade; deaerated before use.	Six hours to freeze; 1-2.5 cm crystals; translucent. C_6H_6: benzene; rod axis parallel to principal axis. $C_6H_5NO_2$: nitrobenzene.	A-1; B-2; C-1; D-1(8); E-2; F-4; G-3; O-6.	D. S. Dillard and K. D. Timmerhaus (1969).
D. -CH_4	99.99 pure.	10 mm diameter grains.	A-3; B-1; C-1; D-1(2); E-5; F-4; G-3; O-3.	D. E. Daney (1971).

3.6. GLASSES AND DISORDERED DIELECTRICS


DISORDERED DIELECTRICS
FIGURE 67a
S.S.T. - porcelain
S. - Pyrex
B. - Phoenix
K.M.K. - glass
W.W. - Phoenix
B. - 1 - quartz
B. - 2 - quartz
B. - 3 - quartz
THERMAL CONDUCTIVITY, mW/cm K
TEMPERATURE, K
20
10
8
6
5
4
3
2
1
.8
.6
.5
.4
.3
.2
4
5
6
8
10
20
30
40
50
60
80
100
200
300


DISORDERED
DIELECTRICS
FIGURE 67b
THERMAL CONDUCTIVITY, mW/cm K
TEMPERATURE, K
10
8
6
5
4
3
2
1
.8
.6
.5
.4
.3
.2
.1
1
1.5
2
3
4
5
6
7
8
9
10
C.-I(b)-silica
C.-I(a)-silica
C.-I-silica
Bj.-J.G. 20
Bj.-J 16 III
C.J. - crown glass
C.J. - soda lime glass
B.-3-quartz
B.-Phoenix
B.-Perspex
Bj.-Monax
Bj.-T.
F.-SiO2
C.J.-Fotoceram
F.-Pyrex
C.J.-2-Pyroceram
C.J.-1-Pyroceram

DISORDERED DIELECTRICS
(See FIGURES 67a and 67b)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Quartz glass.	k = 13.9 mW/cm-K at 273 K; k = 11.6 mW/cm-K at 195 K; k = 6.6 mW/cm-K at 83 K.	A-1; B-2; C-1; D-1(2); F-4; G-3.	A. Eucken (1911a).
S.-Pyrex	. . . . .	Free from observable air-bubbles.	A-8; B-3; C-1; D-2(1); F-5; G-3.	R. W. B. Stephens (1932).
. . . . .	Thuringian glass.	k = 0.334 mW/cm-K at 1.3 K.	A-1; B-6; C-1; D-5(2); F-4; G-3.	P. H. Keesom (1945).
W. W.-Phoenix	Grainger and Threlfall; Phoenix glass.	Phoenix glass, a boro-silicate glass.	A-1; B-1; C-2; D-5(1); E-5; F-4; G-3.	K. R. Wilkinson and J. Wilks (1949).
Bj.-J. G. 20, T., J16III, Monax	J. G. 20: Jena Gerate 20 glass. T: Thuringian glass. J16III: Jena 16 III glass. Monax.	. . . . .	A-1; B-1; C-1; D-2(2); E-5; F-4; G-3; P-4.	D. Bijl (1949).
B.-1, 2, 3-quartz	Quartz glass.	#1: diameter of 0.77 cm, length of 2.25 cm. #2: diameter of 0.74 cm, length of 4.6 cm. #3: diameter of 0.61 cm, length of 2.3 cm.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-3; O-9; P-5.	R. Berman (1951a).
B-Phoenix	Phoenix: Phoenix glass.	Phoenix: 6.0 mm diameter. Also measured another specimen.	Same as above.	Same as above.
C.-1, 1(a), 1(b)-Silica	Corning Glass; high purity.	Fused vitreous silica. #1: unirradiated; density of 2.1994 g/cm^3; also k = 6.13 mW/cm-K at 13 K. #1(a): irradiated by 1.71×10^{19} fast neutrons/cm^2; density of 2.2412 g/cm^3; also k = 8.23 mW/cm-K at 13.7 K. #1(b): additional irradiation by 4.13×10^{19} fast neutrons/cm^2; density of 2.2602 g/cm^3.	A-1; B-1; C-1; D-3(2); G-3; P-5, 9, 13.	A. F. Cohen (1958).
C. J.-1, 2-Pyroceram	Corning Glass Works.	Glass ceramics. #1: cross section of 0.034 x 1.666 cm. # 2: cross section of 0.130 x 1.607 cm.	A-1; B-4; C-1; D-3(2); E-5; F-4; G-3; O-5, 9; P-4, 5, 9, 15.	G. K. Chang and R. E. Jones (1962).

DISORDERED DIELECTRICS (cont'd)

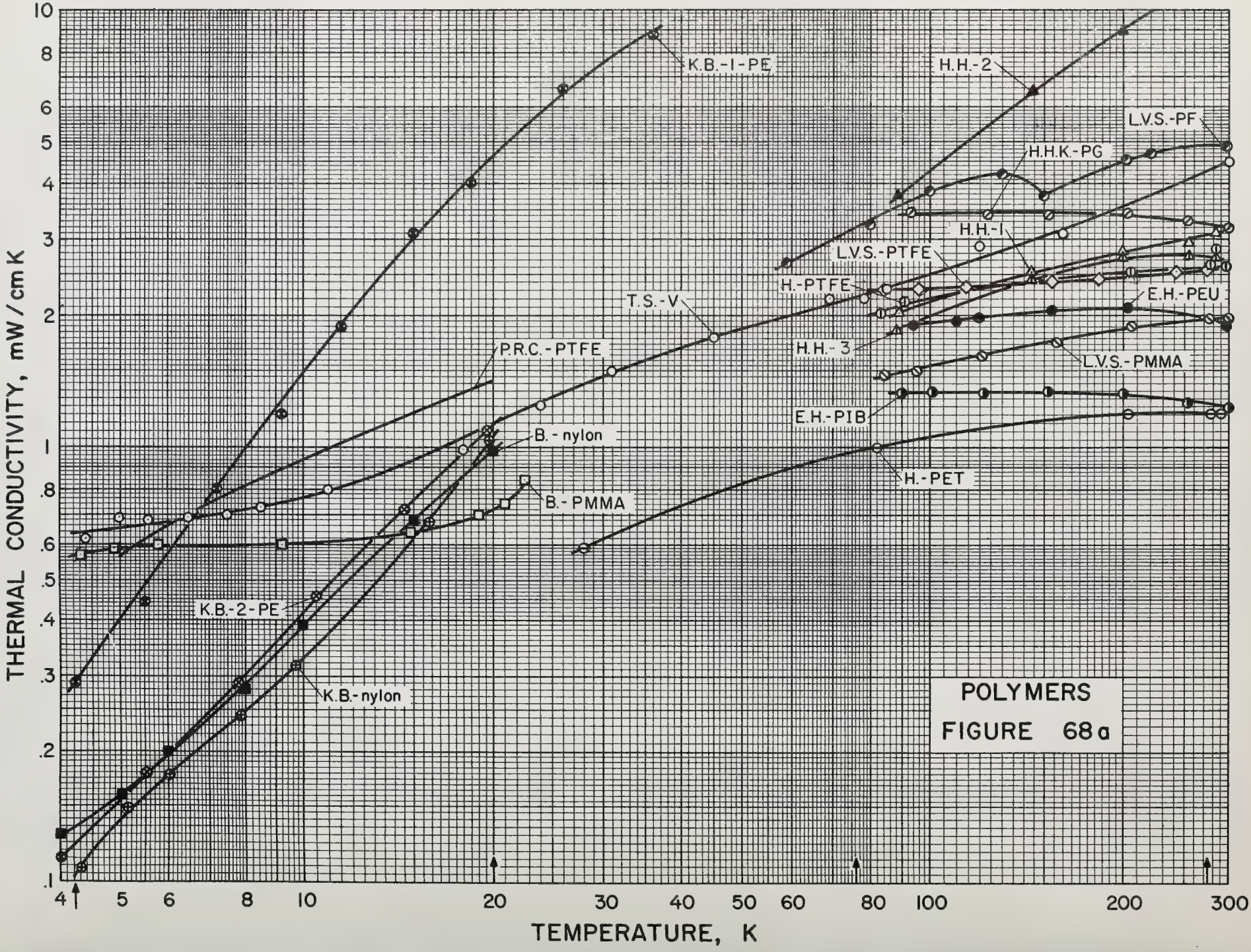
(See FIGURES 67a and 67b)

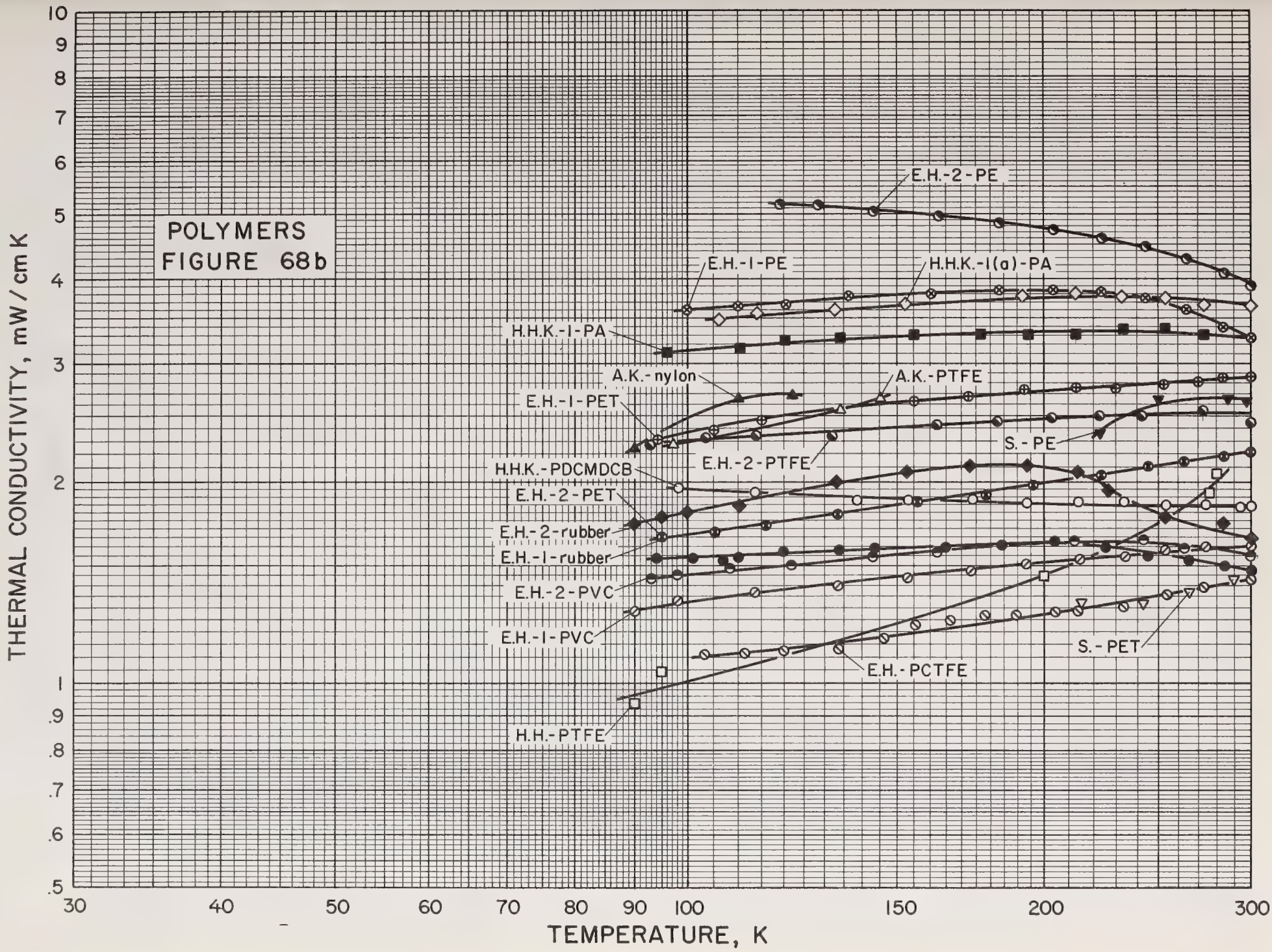
CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
C. J. -Fotoceram, crown glass, soda lime glass	Fotoceram: Corning Glass Works. Crown glass: Fish-Schurman Corp. Soda lime glass: Ednalite Optical Co.	Fotoceram: glass ceramic. Crown glass and soda lime glass: microscope slides intended for use as substrates. Cross section of: crown glass -0.116 x 1.607 cm; soda lime glass -0.1 x 1.588 cm; Fotoceram -0.105 x 1.508 cm.	Same as above.	Same as above.
S.S.T. -porcelain	M. V. Lomonosov Works.	Five specimens of porcelain measured, with results identical within experimental error. Crystallite 70% of volume; glassy matrix 500-2000 Å thick.	A-1; B-1; C-1; D-1(2); E-1; F-4; G-3; O-5; S-3.	E. V. Shadrichev, I. A. Smirnov, and V. V. Tikhonov (1968).
F. -Pyrex; also see FIGURE 76	80.9(weight) SiO_2, 12.19 B_2O_3, 4.24 Na_2O, 2.28 Al_2O_3, 0.11 ZrO_2, 0.02 K_2O, 0.014 Fe^{+2}, <0.01 Li_2O, 0.006±1 Fe^{+3}.	7740 Pyrex; measured in no magnetic field and in magnetic fields up to 9 T; the thermal conductivity was unaffected by the fields. Also measured below 1 K.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-3; P-4, 5; S-3.	R. A. Fisher, G. E. Broadale, E. W. Hornung, and W. F. Giauque (1968).
K. M. K. -glass	. . . . .	Glass S49-2.	A-1; B-1; C-1; D-1(2); E-2; F-2; G-3.	I. N. Krupskii, V. G. Manzhely, and L. A. Koloskova (1968).
F. -SiO_2; also see FIGURE 76	Englehard Industries; iron free.	SiO_2 glass; annealed 3 hrs at 1000°C; no trace of strains; density of 2.202 g/cm^3. Also measured below 1 K.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-3; P-4, 5.	R. A. Fisher, G. E. Brodale, E. W. Hornung, and W. F. Giauque (1969).

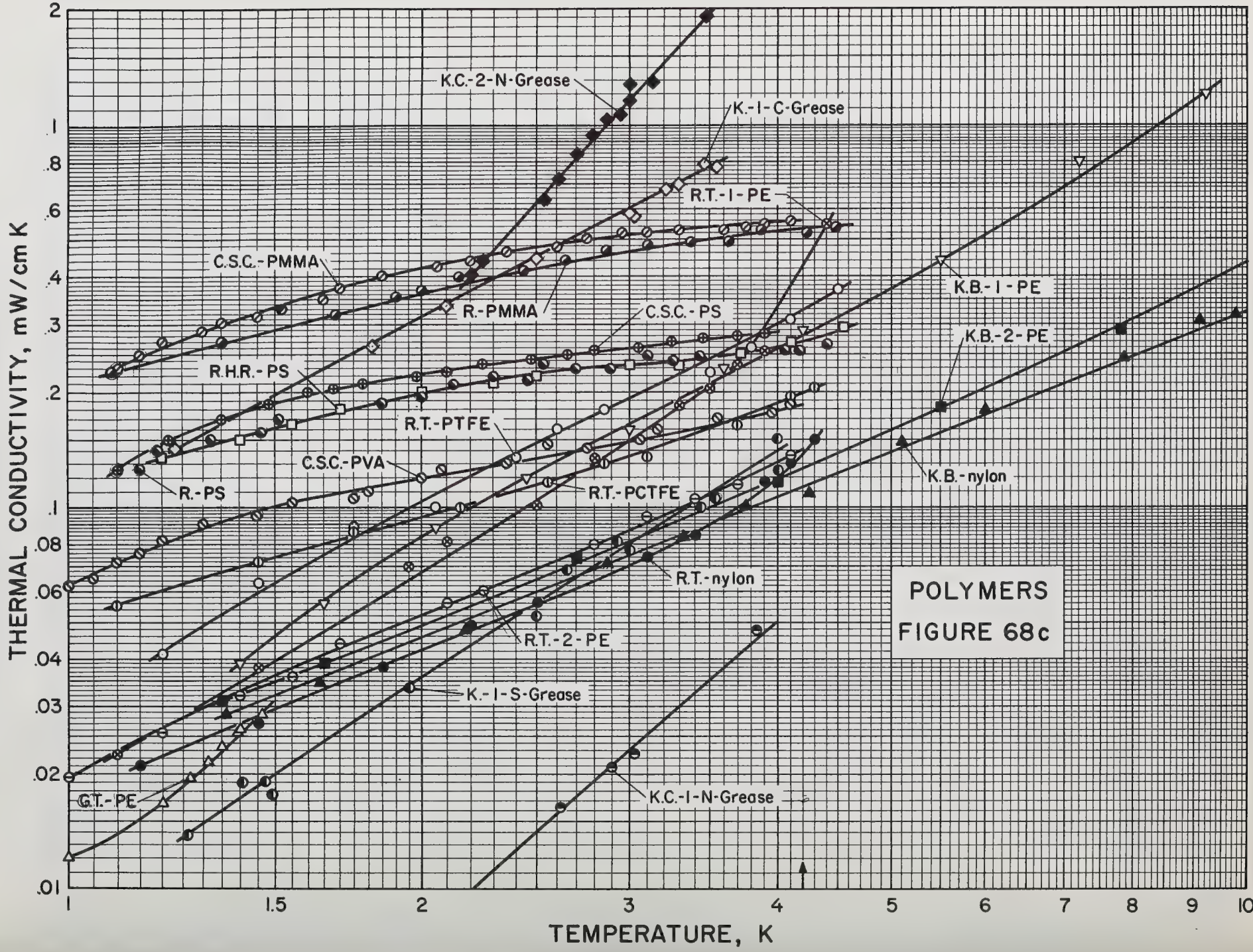
3.7. POLYMERS

Code Names for Plastics

PA	Polyamide
PCTFE	Polychlorotrifluoroethylene
PDCMOCB	Polydichloromethyloxacyclobutane
PE	Polyethylene
PET	Polyethylterapthalate
PEU	Polyesterurethane
PF	Phenolformaldehyde
PG	Polyglycol
PIB	Polyisobutylene
PMMA	Polymethylmethacrylate (plexiglas, perspex)
PS	Polystyrene
PTFE	Polytetrafluoroethylene
PVA	Polyvinylacetate
PVC	Polyvinylchloride


THERMAL CONDUCTIVITY, mW/cm K
TEMPERATURE, K
K.B.-1-PE
H.H.-2
L.V.S.-PF
H.H.K.-PG
H.H.-1
L.V.S.-PTFE
H.-PTFE
T.S.-V
E.H.-PEU
H.H.-3
L.V.S.-PMMA
E.H.-PIB
H.-PET
P.R.C.-PTFE
B.-nylon
B.-PMMA
K.B.-2-PE
K.B.-nylon
POLYMERS
FIGURE 68a


POLYMERS
FIGURE 68b
THERMAL CONDUCTIVITY, mW / cm K
TEMPERATURE, K
10
9
8
7
6
5
4
3
2
1
.9
.8
.7
.6
.5
30
40
50
60
70
80
90
100
150
200
300
E.H.-2-PE
E.H.-1-PE
H.H.K.-1(a)-PA
H.H.K.-1-PA
A.K.-nylon
A.K.-PTFE
E.H.-1-PET
S.-PE
E.H.-2-PTFE
H.H.K.-PDCMDCB
E.H.-2-PET
E.H.-2-rubber
E.H.-1-rubber
E.H.-2-PVC
E.H.-1-PVC
S.-PET
E.H.-PCTFE
H.H.-PTFE


THERMAL CONDUCTIVITY, mW/cm K
TEMPERATURE, K
2
.1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
.01
1
1.5
2
3
4
5
6
7
8
9
10
K.C.-2-N-Grease
K.-1-C-Grease
R.T.-1-PE
C.S.C.-PMMA
R.-PMMA
C.S.C.-PS
K.B.-1-PE
K.B.-2-PE
R.H.R.-PS
R.T.-PTFE
C.S.C.-PVA
R.-PS
R.T.-PCTFE
K.B.-nylon
R.T.-nylon
R.T.-2-PE
K.-1-S-Grease
G.T.-PE
K.C.-1-N-Grease
POLYMERS
FIGURE 68c

POLYMERS

(See FIGURES 68a–68c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	Measured the thermal conductivity of bicycle tube rubber, believed to be pure latex, between 100 and 290 K.	. . . . .	A. Schallamach (1940) and (1941).
B. -PMMA	I. C. I. Ltd; perspex plastic.	12. 7 mm diameter.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-3; O-9; P-5.	R. Berman (1951a).
B. -nylon	Imperial Chemical Industries Ltd.	Drawn monofilament, 2 mm in diameter.	A-1; B-1; C-1; D-4(2); E-4; F-4; G-3.	R. Berman, E. L. Foster, and H. M. Rosenberg (1955).
P. R. C. -PTFE	E. I. du Pont.	PTFE: polytetrafluoroethylene; extruded; density of 2. 218 g/cm^3.	A-1; B-1; C-1; D-1(8); E-2; F-3; G-2.	R. L. Powell, W. M. Rogers, and D. O. Coffin (1957).
. . . . .	. . . . .	Polytetrafluoroethylene: density of 2. 19 g/cm^3; crystallinity ~ 65%; k = 2. 14 mW/cm-K at 0°C; k = 2. 13 mW/cm-K at 20°C. Polystyrene: density of 1. 06 g/cm^3; 0% crystallinity; k = 1. 33 mW/cm-K at 0°C. Polyhexamethylene adipamide: density of 1. 15 g/cm^3; ~ 40% crystallinity; k = 2. 43 mW/cm-K at 0°C. Polymerized epoxy: #1-85 parts resin, 15 parts catalyst, k = 1. 75 mW/cm-K at 0°C; #2-85 parts resin, 15 parts catalyst, and 130 parts Aℓ powder, k = 6. 30 mW/cm-K at 0°C.	A-8; B-1; C-1; D-1(1); F-5; G-3.	D. E. Kline (1961).
H. H. -PTFE	E. I. du Pont.	PTFE: polytetrafluoroethylene (Teflon). Also measured specimen of Teflon composite. Also measured 13 other plastic foam specimens.	A-7; B-4; C-1; D-1(12); E-5; F-4; G-3.	J. F. Haskins and J. Hertz (1962); see also J. F. Haskins, M. D. Campbell, J. Hertz, and J. L. Percy (1964).

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POLYMERS (cont'd)
(See FIGURES 68a–68c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	Osaka Kinzoku Kogyo Co. #1: PTFE: polytetrafluoroethylene. #2: PCTFE: polytrifluorochloroethylene.	#1(a): quenched by keeping 4 hrs at 350°C; cooled rapidly in ice water; k = 2.52 mW/cm-K at 289 K and 300 K. #1(b): specimen #1(a) annealed 30 min at 200°C; cooled slowly to room temperature; k = 4.39 mW/cm-K at 294 K. #2(a): heated 30 min at 200°C, cooled rapidly in ice water; density of 2.116 g/cm^3; degree of crystallinity 0.286; k = 1.16 mW/cm-K at 288 K; k = 1.04 mW/cm-K at 297 K. #2(b): specimen #2(a) heated 30 min at 190°C, quenched in ice water; density of 2.140 g/cm^3; degree of crystallinity 0.716; k = 1.86 mW/cm-K at 291 K. #2(c): specimen #2(b) heated 4 hrs at 190°C, cooled slowly to room temperature; density of 2.147 g/cm^3; degree of crystallinity 0.841; k = 2.06 mW/cm-K at 293 K. #2(d): specimen #2(c) heated 30 min at 220°C, heated 4 hrs at 170°C, cooled slowly to room temperature; density of 2.151 g/cm^3; degree of crystallinity 0.913; k = 2.34 mW/cm-K at 293 K.	. . . . .	M. Hattori (1962).
E.H.-1,2-PE	. . . . .	PE: polyethylene. #1: high pressure. #2: low pressure.	. . . . .	K. Eiermann and K.-H. Hellwege (1962); see also K. Eiermann (1961) and (1964).
E.H.-PCTFE	. . . . .	PCTFE: polychlorotrifluoroethylene.	. . . . .	Same as above.
E.H.-1,2-PET	. . . . .	PET: polyethylene terephthalate. #1: density of 1.409 g/cm^3. #2: density of 1.337 g/cm^3.	. . . . .	Same as above.
E.H.-PTFE	. . . . .	PTFE: polytetrafluoroethylene.	. . . . .	Same as above.

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POLYMERS (cont'd)
(See FIGURES 68a–68c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
E.H.-PEU, PIB	. . . . .	PEU: polyesther urethane. PIB: polyisobutylene.	. . . . .	K. Eiermann and K.-H. Hellwege (1962); see also K. Eiermann (1961) and (1964).
E.H.-1,2-rubber	. . . . .	#1: natural rubber. #2: silicone rubber.	. . . . .	Same as above.
E.H.-1,2-PVC	. . . . .	PVC: polyvinyl chloride. #1: 10% plasticizer content. #2: 40% plasticizer content.	. . . . .	Same as above.
See FIGURE 76	. . . . .	Measured nylon, PTFE, PCTFE, and Epibond below 1 K.	. . . . .	A. C. Anderson, W. Reese, and J. C. Wheatley (1963).
H.-PET, PTFE	PET and PTFE: E. I. du Pont.	PET: polyethylene terephthalate (Mylar); formed and slow-cooled film, 0.036 cm thick; density of 1.39 g/cm^3. PTFE: polytetrafluoroethylene (Teflon).	A-7; B-4; C-1; D-1(12); E-5; F-4; G-3.	J. F. Haskins, M. D. Campbell, J. Hertz, and J. L. Percy (1964); see also Hertz and Haskins (1965).

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POLYMERS (cont'd)
(See FIGURES 68a–68c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
. . . . .	. . . . .	PTFE: polytetrafluoroethylene. (a): untreated; machined; density of 2.154 g/cm^3; crystallinity of 54%; molecular weight $\sim 10^7$; k = 2.72 mW/cm-K at 20°C. (b): held 2 weeks at 340°C, cooled at rate of 0.15°C/min, at every 5°C decrement temperature maintained for 24 hrs, cooled continuously from 100°C; density of 2.235 g/cm^3; crystallinity of 78%; molecular weight $\sim 10^7$; k = 2.42 mW/cm-K at 20°C. (c): heated 18 hrs at 350°C, quenched in liquid nitrogen; density of 2.132 g/cm^3; crystallinity of 45%; molecular weight $\sim 10^7$; k = 1.94 mW/cm-K at 20°C. (d): irradiated by Co^{60} γ-rays at dose of 4.7 Mrad; density of 2.198 g/cm^3; crystallinity of 67%; molecular weight $\sim 6 \times 10^5$; k = 2.56 mW/cm-K. (e): irradiated by Co^{60} γ-rays at dose of 190 Mrad; density of 2.222 g/cm^3; crystallinity of 74%; molecular weight $\sim 2 \times 10^4$; k = 2.42 mW/cm-K.	A-8; B-1, 6; C-1; D-1(1); F-5; G-3; O-1; P-13.	K.-L. Hsu, D. E. Kline, and J. N. Tomlinson (1965).
R.T.-1, 2-PE	PE: polyethylene. #1: Phillips Petroleum Co.; ethyl branches added.	#1: Marlex I; pellets heated to 155°C under pressure of 1000 psi, cast into rods, cooled 12 hrs to room temperature; density of 0.964 g/cm^3; crystallinity of 84.8%. #2: Marlex II; low density; density of 0.917 g/cm^3; crystallinity of 51.2%; ethyl branches added to impede crystallization. Another specimen of Marlex measured, with results between #1 and #2.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-4; P-4; S-3.	W. Reese and J. E. Tucker (1965).
R.T.-PTFE, PCTFE, nylon	PTFE and PCTFE: E. I. duPont.	PTFE: polytetrafluoroethylene (Teflon); density of 2.155 g/cm^3. PCTFE: polychlorotrifluoroethylene (Kel-F); density of 2.114 g/cm^3. Nylon: density of 1.140 g/cm^3.	Same as above.	Same as above.

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POLYMERS (cont'd)

(See FIGURES 68a–68c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
H. H. -1, 2, 3	#1: Dow. #2: Monsanto. #3: resin trade name of CTL-91-LD.	#1: epoxy resin type (YM-31-A-glass); roving form, HTS finish; cross-plied at angles of 57° and 303°; cure temperature of 300°F. #2: phenolic resin type (Graphite); WCB style, fabric form; parallel laminate; cure temperature 325°F. #3: phenolic resin type (SN-19 Nylon); YN-25 style; chopped fabric 1/2 x 1/2" form; heat set and scoured finish; random molded layup; cure temperature of 325°F. Also measured 12 other specimens.	. . . . .	J. Hertz and J. F. Haskins (1965).
L. V. S. -PTFE, PF, PMMA	. . . . .	PTFE: polytetrafluoroethylene. PF: phenol-formaldehyde, with fiber glass. PMMA: polymethylmethacrylate.	O-1; P-4.	A. V. Luikov, L. L. Vasiliev, and A. G. Shashkov (1965).
R. -PS, PMMA	PMMA: Rohn and Haas Co.	PS: polystyrene; extruded rod. PMMA: polymethylmethacrylate. Also measured another PMMA, heated at 190°C; results 5-10% greater than R. -PMMA. Also measured Berman's perspex specimen, with results 5% lower than B. -Perspex.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-3; O-9; P-4.	W. Reese (1966a); see also W. Reese (1966b).
S. -PET, Pe	PET: E. I. duPont.	PET: polyethylene terephthalate (Mylar); type-A. PE: polyethylene; low density.	O-1; P-4.	R. C. Steere (1966).
. . . . .	Polytetrafluoroethylene.	(a): sintered plates maintained at 390°C, quenched at -10°C, surface skived flat; density of 2.142 g/cm^3; crystallinity of 48.1%; k = 2.48 mW/cm-K at 260 K; k = 2.44 mW/cm-K at 273 K; k = 2.51 mW/cm-K at 293 K. (b): sintered plates maintained at 376°C for 4 hrs, cooled to 319°C at rate of 30°C/hr, cooled to 227°C at rate of 6°C/hr, cooled naturally; density of 2.185 g/cm^3; crystallinity of 61.8%; k = 2.65 mW/cm-K at 244 K; k = 2.68 mW/cm-K at 273 K; k = 2.43 mW/cm-K at 293 K.	A-7; B-4; C-1.	T. Ozawa and K. Kanari (1967).

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POLYMERS (cont'd)

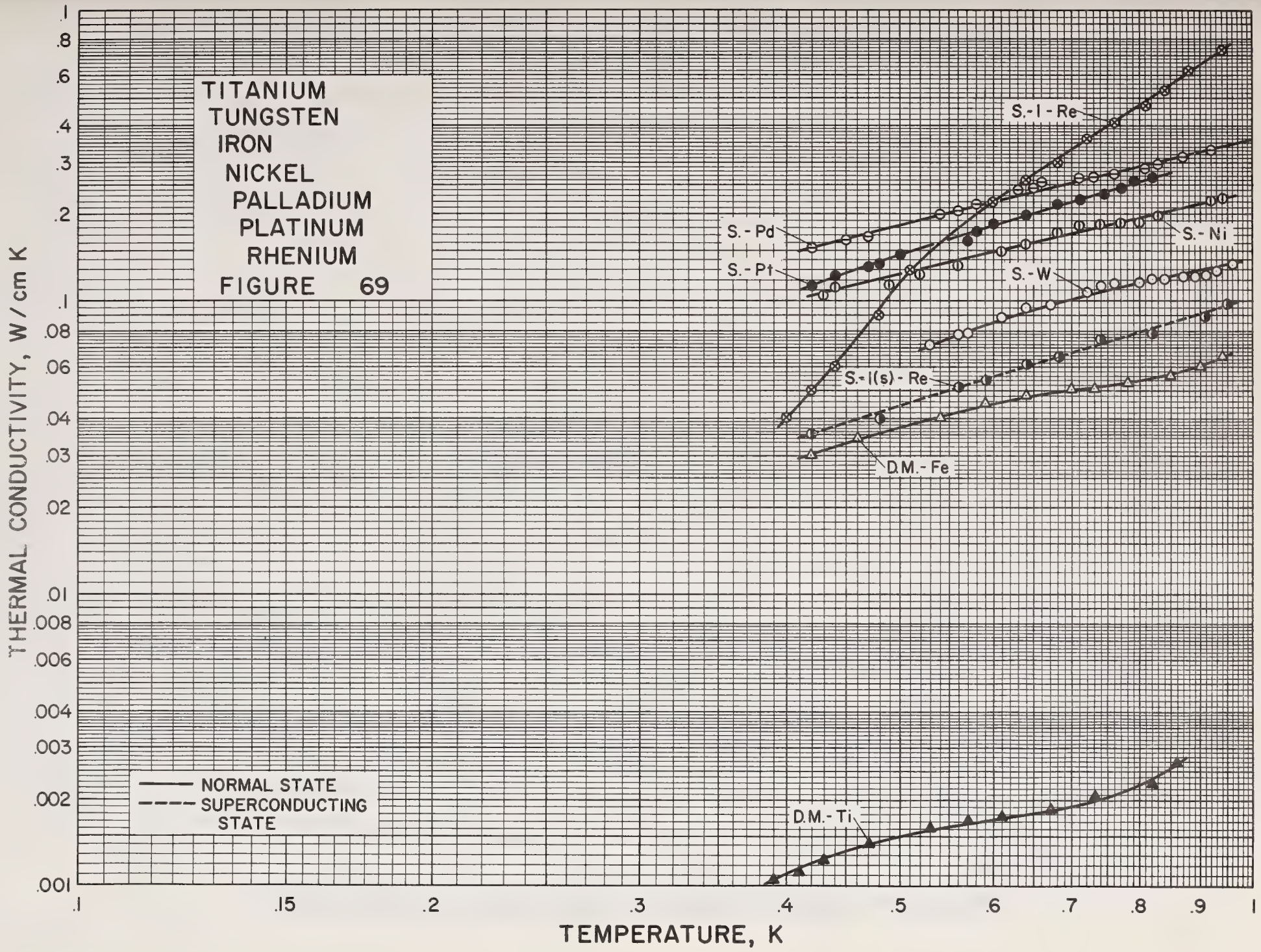
(See FIGURES 68a–68c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
A.K.-PTFE, nylon	E. I. duPont; polytetrafluoroethylene AMS 3651. Nylon: nylon 101.	PTFE: polytetrafluoroethylene (Teflon).	A-1; B-1; C-1; D-1(3); F-4; G-3.	J.G. Androulakis and R.L. Kosson (1968).
H.H.K.-PG, PDCMOCB, 1-PA, 1(a)-PA	PG: 1,2-ethanediol; Farbwerke Hoechst. PDCMOCB: Hercules. PA: BASF.	PG: polyglycol; density of 1.210 g/cm^3; crystallinity of 81%. PDCMOCB: poly-3,3-dichloromethyloxacyclo butane; density of 1.407 g/cm^3; crystallinity of 21%. PA: 6,6-polyamid. #1: held in normal air atmosphere; density of 1.1501 g/cm^3; 1.5% volume water. #1(a): annealed at 140°C, soaked in H_2O at 20°C; density of 1.1533 g/cm^3; 8.1% volume water.	P-7.	K.-H. Hellwege, R. Hoffman, and W. Knappe (1968).
K.B.-1,2-PE	. . . . .	PE: polyethylene. #1: compression molded; machined; density of 0.971 g/cm^3; spherulite rings spaced at 7.5μ. #2: commercially extruded; density of 0.914 g/cm^3; no distinguishable spherulites. Two other specimens of intermediate densities also measured, with intermediate results.	A-1; B-1; C-1; D-3(2); E-2, 3, 5; F-4; G-3; O-9; P-4.	R.J. Kolouch and R.G. Brown (1968).
K.B.-nylon	Nylon-66.	Cut from compression molded bars; density of 1.141 g/cm^3; spherulite size of 13.4μ.	Same as above.	Same as above.
R.H.R.-PS	Commercial; molecular weight ~1.92 x 10^6.	PS: polystyrene; cut from extruded rod; unirradiated. Specimen also measured after irradiation by 80-MeV electron beam to three different dose levels, cooled to below 50°C during irradiation, with no significant change in thermal conductivity.	A-1; B-1; C-1; D-3(2); E-3; F-4; G-3; P-13; S-3.	W. Reese, P.J. Higgins, and G.W. Rostine (1968).
See FIGURE 76	Polystyrene.	Measured below 1 K.	. . . . .	B.L. Berman, R.P. Madding, and J.R. Dillinger (1969).
T.S.-V	General Electric; varnish, composed of vinyl modified phenolic.	General Electric #7031 thermosetting adhesive varnish; heated 3 days at 90°C in air.	A-1; B-2; C-1; D-1(2); E-1; F-2; G-3; P-1.	J.H. Taggart and G.H. Slack (1969).

POLYMERS (cont'd)
(See FIGURES 68a-68c)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
G. T. -polyethylene; also see FIGURE 76	Commercial.	Density of 0.947 g/cm^3; fractional crystallinity ~65%. Also measured below 1 K.	A-1; B-1; C-1; D-3(4); E-5; F-4; G-3; O-9.	M. Giles and C. Terry (1969).
K. -1-C-Grease -S-Grease	C-Grease: Air Products; S-Grease: Dow-Corning.	Vacuum greases mounted in nylon tubes. C-Grease labelled Cry-Con is a copper loaded grease. S-Grease is a silicone lubricant. Another specimen, silicones plus fillers, labelled Eccotherm TC-4 had values about 10% above the S-Grease.	A-1; B-1; C-1; D-3(3); E-5; F-4; G-3.	M. M. Kreitman (1969).
C.S.C. - PMMA, PS, PVA; also see FIGURE 76	PMMA: E. I. duPont. PVA: Shawinigan Resins.	PMMA: polymethylmethacrylate (Lucite II); average molecular weight of 1.6×10^5; density of 1.185 g/cm^3. PS: polystyrene; average molecular weight of 1.792×10^5; density of 1.04 g/cm^3. PVA: polyvinyl acetate; density of 1.20 g/cm^3. Also measured below 1 K.	A-1; B-1; C-1; D-3(2); F-4; G-3; O-9; P-4, 7; S-3.	C. L. Choy, G. L. Salinger, and Y. C. Chiang (1970).
K. C. -1, 2-N-Grease	Assoc. Elect. Ind.	Apiezon-N vacuum grease mounted in nylon tube. Specimen 1 was evacuated to 2000 μ of helium gas before cooling. Specimen 2 was cooled to 77 K in an atmosphere of helium gas, then evacuated and cooled to 4 K.	A-1; B-1; C-1; D-3(3); E-5; F-4; G-3.	M. M. Kreitman and J. T. Callahan (1971).

3.8. VERY LOW TEMPERATURE DATA (T<1 K)


TITANIUM
TUNGSTEN
IRON
NICKEL
PALLADIUM
PLATINUM
RHENIUM
FIGURE 69
S.-I-Re
S.-Pd
S.-Pt
S.-Ni
S.-W
S.-I(s)-Re
D.M.-Fe
D.M.-Ti
NORMAL STATE
SUPERCONDUCTING STATE
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
.01
.008
.006
.004
.003
.002
.001
.1
.15
.2
.3
.4
.5
.6
.7
.8
.9
1

TITANIUM, TUNGSTEN, IRON, NICKEL, PALLADIUM, PLATINUM, and RHENIUM

(See FIGURE 69) (temperatures below 1 K)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
		TITANIUM		
D.M.-Ti	. . . . .	Single crystal.	L-1; M-6.	G. Davey and K. Mendelssohn (1963).
		TUNGSTEN		
S.-W	Lamp & Metals, Ltd.; RRR(20) = 30.	Polycrystalline wire.	A-1; B-5; C-1; D-3(2); E-5; F-4; G-3; M-1; O-5; P-4; Q-1.	J.K.N. Sharma (1967a).
		RHENIUM		
S.-1, 1(s)-Re	Materials Research Corp.; 99.994% pure; RRR(20) ≃ 2000.	Single crystal. Measured in both the normal (in magnetic field of 0.045 T) and superconducting (s) states. Graph of lattice conductivity and lattice conductivity due to boundary scattering. Graph of ratio of superconducting to normal thermal conductivity as a function of reduced temperature.	A-1; B-5; C-1; D-3(2); E-5; F-4; G-3; M-1; N-3; O-5; P-4, 5; Q-1.	J.K.N. Sharma (1967a) and (1967b).
		IRON		
D.M.-Fe	99.97% pure.	. . . . .	L-1; M-6.	G. Davey and K. Mendelssohn (1963).
		NICKEL		
S.-Ni; also see FIGURE 15b	Johnson, Matthey 37043; 99.995% pure; RRR(20) = 100.	Also measured above 1 K.	A-1; B-5; C-1; D-3(2); E-5; F-4; G-3; M-1; O-5; P-4; Q-1.	J.K.N. Sharma (1967a).
		PALLADIUM		
S.-Pd	Johnson, Matthey 36949; 99.999% pure; RRR(20) = 171.	. . . . .	Same as above.	Same as above.

TITANIUM, TUNGSTEN, IRON, NICKEL, PALLADIUM, PLATINUM, and RHENIUM (cont'd)

(See FIGURE 69) (temperatures below 1 K)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
		PLATINUM		
S.-Pt	Johnson, Matthey 39081; 99.999% pure; RRR(20) = 148.	. . . . .	A-1; B-5; C-1; D-3(2); E-5; F-4; G-3; M-1; O-5; P-4; Q-1.	J. K. N. Sharma (1967a).

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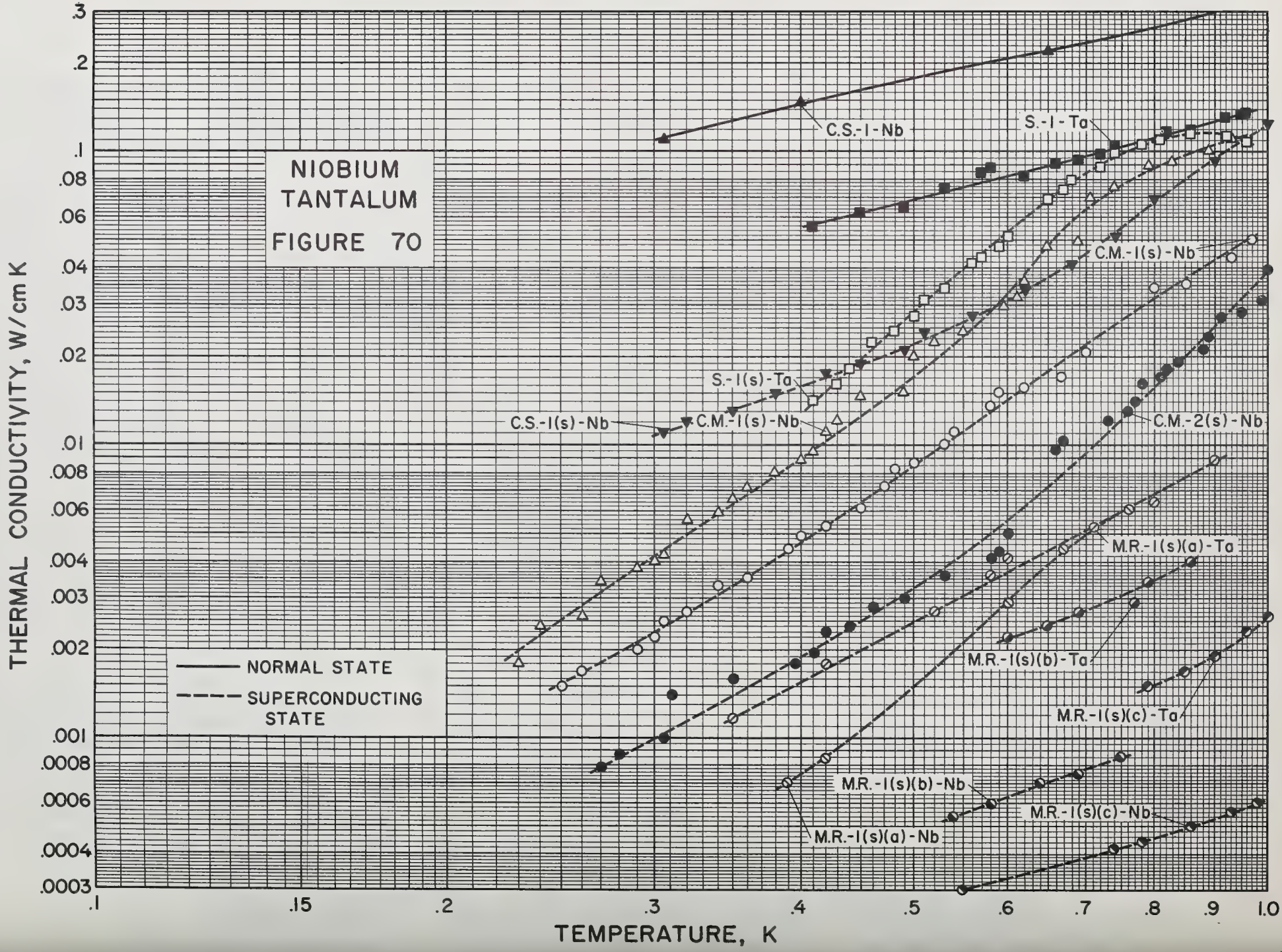
NIOBIUM
TANTALUM
FIGURE 70
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
NORMAL STATE
SUPERCONDUCTING STATE
C.S.-I-Nb
S.-I-Ta
C.M.-I(s)-Nb
S.-I(s)-Ta
C.S.-I(s)-Nb
C.M.-I(s)-Nb
C.M.-2(s)-Nb
M.R.-I(s)(a)-Ta
M.R.-I(s)(b)-Ta
M.R.-I(s)(c)-Ta
M.R.-I(s)(b)-Nb
M.R.-I(s)(c)-Nb
M.R.-I(s)(a)-Nb
.3
.2
.1
.08
.06
.04
.03
.02
.01
.008
.006
.004
.003
.002
.001
.0008
.0006
.0004
.0003
.1
.15
.2
.3
.4
.5
.6
.7
.8
.9
1.0

NIOBIUM and TANTALUM

(See FIGURE 70)

(temperatures below 1 K)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
		NIOBIUM		
M.R. -1(s)(a), 1(s)(b), 1(s)(c)-Nb; also see FIGURE 9	Johnson, Matthey 4526; 99.99% pure.	Measured in the superconducting (s) state. Circular cross section of 0.47 cm diameter. Same specimen measured three times; (b) and (c) indicate frozen-in flux due to no magnetic shielding. Also measured above 1 K; See M.R. on NIOBIUM Table in "Elements" section.	A-1; B-1; C-1; D-3(2); E-6; F-4; G-3; M-1; N-3; P-4, 5; Q-1.	K. Mendelssohn and C. A. Renton (1953) and (1955).
C.M. -1(s), 2(s)-Nb; also see FIGURE 9	Johnson, Matthey; 3 ppm (weight) Cu and Mg. #1: RRR(20) = 120. #2: RRR(20) = 60.5.	Single crystals; prepared by floating-zone melting. Diamond pyramid hardness of: #1, 75; #2, 66. Measured in superconducting (s) state. Graph of the ratio of superconducting to normal thermal conductivity as a function of reduced temperature. Also measured above 1 K.	A-1; B-1; C-1; D-3(2); E-5, 6; F-4; G-2; M-2; N-3; O-5; P-5; Q-1.	A. Connolly and K. Mendelssohn (1962).
C.S. -1, 1(s)-Nb	Wah Chang Corp.; major impurities of Ta and W.	Single crystal; specimen size of 0.47 x 10 cm; transition temperature of 9.25 K. Measured in the superconducting (s) state.	A-1; B-1; C-1; D-1(4); E-5, 8; F-4; G-2; N-3, 5; P-4, 5.	J.R. Carlson and C.B. Satterthwaite (1970).
. . . . .	Specimen #1, RRR = 2000, < 10^2 ppm(atomic)Ta; #2, RRR = 26, 10^4 ppm Ta.	Measured two single-crystal specimens between 0.04 and 4 K. Surfaces roughened with 26μ abrasive. #1 - 0.304 cm diam., #2 - 0.315 cm diam. Conductivity size limited below 0.2 K, Specimen #1, K = .022 mW/cm K at 0.04 K, 1.4 mW/cm K at 0.2 K with specimen #2 about 5-10% higher. Specimen # 1, K = 100 mW/cm K at 1 K; #2, 40 mW/cm K at 1 K.	A-1; B-1; C-1; D-3(2); E-5, 6; F-4; G-3; M-1; N-3; P-5; Q-1.	A.C. Anderson, C.B. Satterthwaite, and S.C. Smith (1971).

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NIOBIUM and TANTALUM (cont'd)

(See FIGURE 70) (temperatures below 1 K)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
		TANTALUM		
M.R.-1(s)(a), 1(s)(b), 1(s)(c)-Ta; also see FIGURE 10	Johnson, Matthey 3804; 99.98% pure; RRR(20) = 19.7.	Measured in the superconducting (s) state. Same specimen measured three times; (b) and (c) indicate 'frozen in' flux due to no magnetic shielding. Also measured above 1 K. See M.R. and R. on TANTALUM Table in "Elements" section.	A-1; B-1; C-1; D-3(2); E-6; F-4; G-3; N-3; Q-1.	K. Mendelssohn and C. A. Renton (1953) and (1955).
C.M.-1(s)-Ta; also see FIGURE 10	Services Electronic Research Lab. 0.005% Fe, 0.003% Si, 3 ppm O_2, 2.5 ppm H_2; RRR(20) = 47.	Single crystal; prepared by floating-zone melting. Diamond pyramid hardness of 75. Measured in superconducting (s) state. Graph of the ratio of superconducting to normal thermal conductivity as a function of reduced temperature. Also measured above 1 K.	A-1; B-1; C-1; D-3(2); E-5, 6; F-4; G-3; M-2; N-3; O-5; P-5; Q-1.	A. Connolly and K. Mendelssohn (1962).
S.-1, 1(s)-Ta; also see FIGURE 10	Murex; 99.994% pure; RRR(20) = 80.	Single crystal; prepared by electron-beam zone refining technique. Measured in both the normal (in magnetic field of 0.15 T) and superconducting (s) states. Graph of ratio of superconducting to normal thermal conductivity as a function of reduced temperature. Graph of lattice conductivity in the normal and superconducting states. Also measured above 1 K.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-3; M-1; N-3; O-5; P-4, 5; Q-1.	J. K. N. Sharma (1967a) and (1967b).

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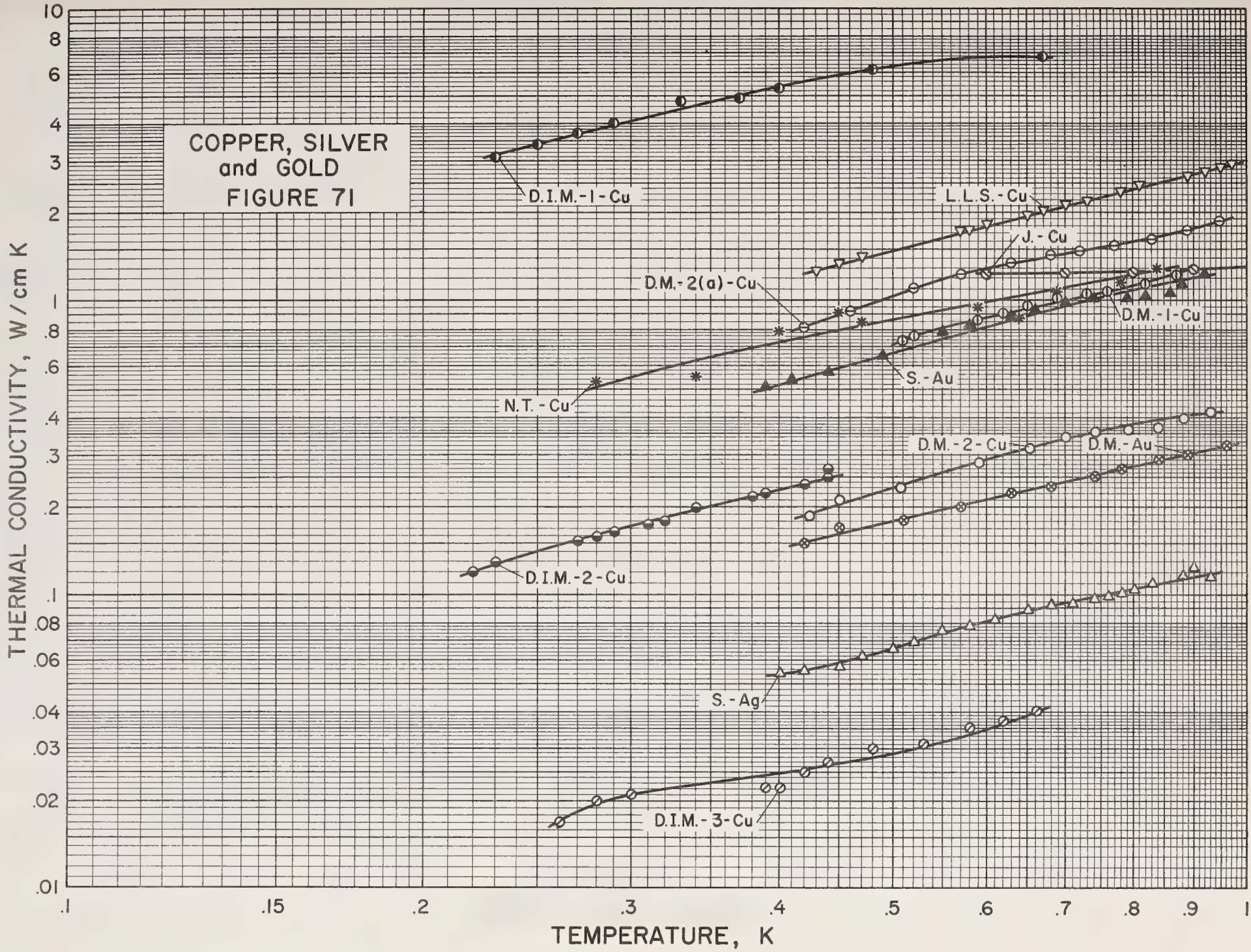
COPPER, SILVER
and GOLD
FIGURE 71
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
.01
.1
.15
.2
.3
.4
.5
.6
.7
.8
.9
1
D.I.M.-1-Cu
L.L.S.-Cu
J.-Cu
D.M.-2(a)-Cu
D.M.-1-Cu
S.-Au
N.T.-Cu
D.M.-2-Cu
D.M.-Au
D.I.M.-2-Cu
S.-Ag
D.I.M.-3-Cu

COPPER, SILVER, and GOLD

(See FIGURE 71)

(temperatures below 1 K)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
		COPPER		
N. T. -Cu; see also FIGURE 43d	General Electric; "commercial grade high-purity".	Magnet wire. Also measured above 1 K.	A-1; B-5; C-1; D-6(2); E-6; F-4; G-3; L-1; M-1.	J. Nicol and T. P. Tseng (1953).
D. M. -1, 2, 2(a)-Cu	#1: commercial. #2: 99.999% pure.	#1 and #2: polycrystalline. #2(a): specimen #2 annealed 3 hrs at 625°C.	L-1; M-6.	G. Davey and K. Mendelssohn (1963).
D. I. M. -1, 2, 3-Cu	#1: Société Metallurgique de Hoboken; < 10 ppm unknown. #2: Johnson, Matthey CB8; doped; 2 ppm Fe and Si, 1 ppm Co and Ni, 0.5 ppm Mn. #3: Johnson, Matthey CB2; doped; 160 ppm Si, 140 ppm Ni, 130 ppm Mn, 110 ppm Fe, 97 ppm Co.	Two other specimens of intermediate dopant concentration also measured, with intermediate results.	M-2.	A. Dupré, A. van Itterbeek, and L. Michiels (1964).
J. -Cu; also see FIGURE 43c	Copper wire; RRR ≃ 85.	Also measured above 1 K.	A-1; B-1; C-1; D-3(2); E-5, 6; F-4; G-2; M-1; P-2, 4; Q-1; S-1.	M. H. Jericho (1965).
L. L. S. -Cu; also see FIGURE 43d	Chase Brass and Copper; RRR = 270.	Annealed 3 hrs at 530°C. Also measured above 1 K.	A-1; B-5; C-1; D-3(2); E-3, 5, 6; F-4; G-3; M-1.	P. Lindenfeld, E. A. Lynton, and R. Soulen (1965).
		SILVER		
S. -Ag	Johnson, Matthey 24757; 99.999% pure; RRR(20) = 115.	. . . . .	A-1; B-5; C-1; D-3(2); E-5; F-4; G-3; M-1; O-5; P-4; Q-1.	J. K. N. Sharma (1967a); see also K. Mendelssohn, J. K. N. Sharma, and I. Yoshida (1965).

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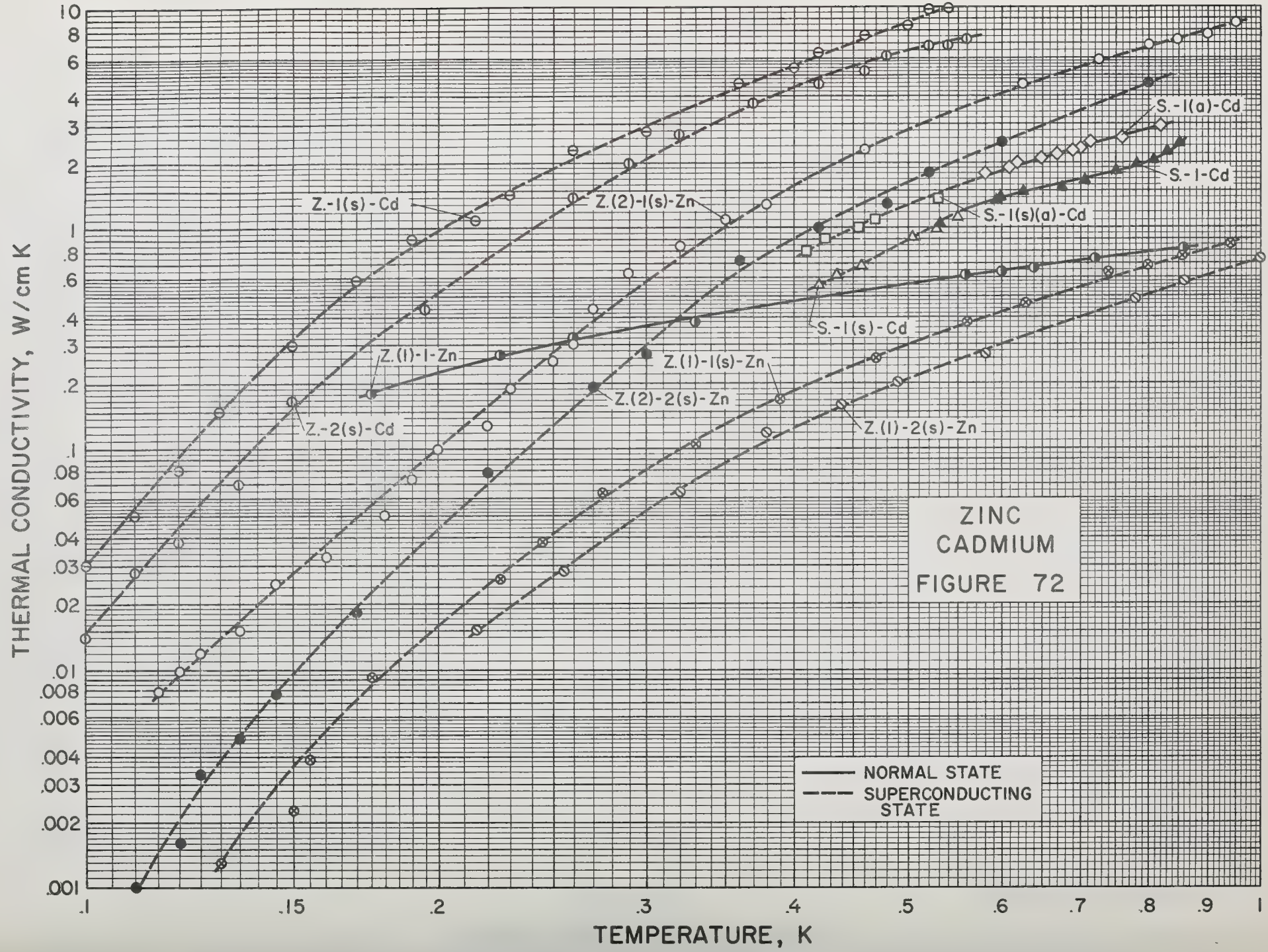
COPPER, SILVER, and GOLD (cont'd)

(See FIGURE 71)

(temperatures below 1 K)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
		GOLD		
D.M.-Au	99.99% pure.	. . . . .	L-1; M-6.	G. Davey and K. Mendelssohn (1963).
S.-Au	Johnson, Matthey 34418; 99.999% pure; RRR(20) = 146.	. . . . .	A-1; B-5; C-1; D-3(2); E-5; F-4; G-3; M-1; O-5; P-4; Q-1.	J. K. N. Sharma (1967a); see also K. Mendelssohn, J. K. N. Sharma, and I. Yoshida (1965).


THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
.01
.008
.006
.004
.003
.002
.001
.1
.15
.2
.3
.4
.5
.6
.7
.8
.9
1
Z.-1(s)-Cd
Z.(2)-1(s)-Zn
S.-1(a)-Cd
S.-1-Cd
S.-1(s)(a)-Cd
S.-1(s)-Cd
Z.(1)-1-Zn
Z.(1)-1(s)-Zn
Z.(2)-2(s)-Zn
Z.-2(s)-Cd
Z.(1)-2(s)-Zn
ZINC
CADMIUM
FIGURE 72
NORMAL STATE
SUPERCONDUCTING STATE

ZINC and CADMIUM

(See FIGURE 72)

(temperatures below 1 K)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
		ZINC		
Z.(1)-1, 1(s), 2(s)-Zn	0.0001% impurities.	Single crystals; grown in thin glass capillaries; rod axis inclined 30° to (001) direction. Measured in both the normal (in longitudinal magnetic field of 0.006 T) and superconducting (s) states. Graph of electronic thermal conductivity as a function of reduced temperature.	A-1; B-1; C-1; D-3(4); E-6; F-4; G-3; M-2; N-3; P-5; Q-1; S-3.	N. V. Zavaritskii (1958b).
Z.(2)-1(s), 2(s)-Zn	. . . . .	Grown along principal crystallographic direction by Kapitza method. #1: rod axis perpendicular to hexagonal axis. #2: rod axis parallel to hexagonal axis. Measured in superconducting (s) state. Transition temperature of 0.825 K. Graph of electronic thermal conductivity in superconducting state as function of reduced temperature. Graph of ratio of electronic thermal conductivity in the superconducting state parallel and perpendicular to hexagonal axis as a function of reduced temperature.	A-1; B-1; C-1; D-3(4); E-6; F-4; G-3; M-2; N-3, 4; O-6; P-5; Q-1; S-3.	N. V. Zavaritskii (1961a).
		CADMIUM		
Z.-1(s), 2(s)-Cd	. . . . .	Same as Z.(2)-1(s), 2(s)-Zn above; transition temperature of 0.53 K.	Same as above.	Same as above.
S.-1, 1(s), 1(a), 1(s)(a)-Cd	Johnson, Matthey 137; 99.999% pure.	#1: extruded. #1(a): then annealed 7 days in vacuum at room temperature. Measured in both the normal and superconducting (s) states.	A-1; B-5; C-1; D-3(2); E-5; F-4; G-3; M-1; N-3; O-5; P-4, 5; Q-1.	J. K. N. Sharma (1967a).

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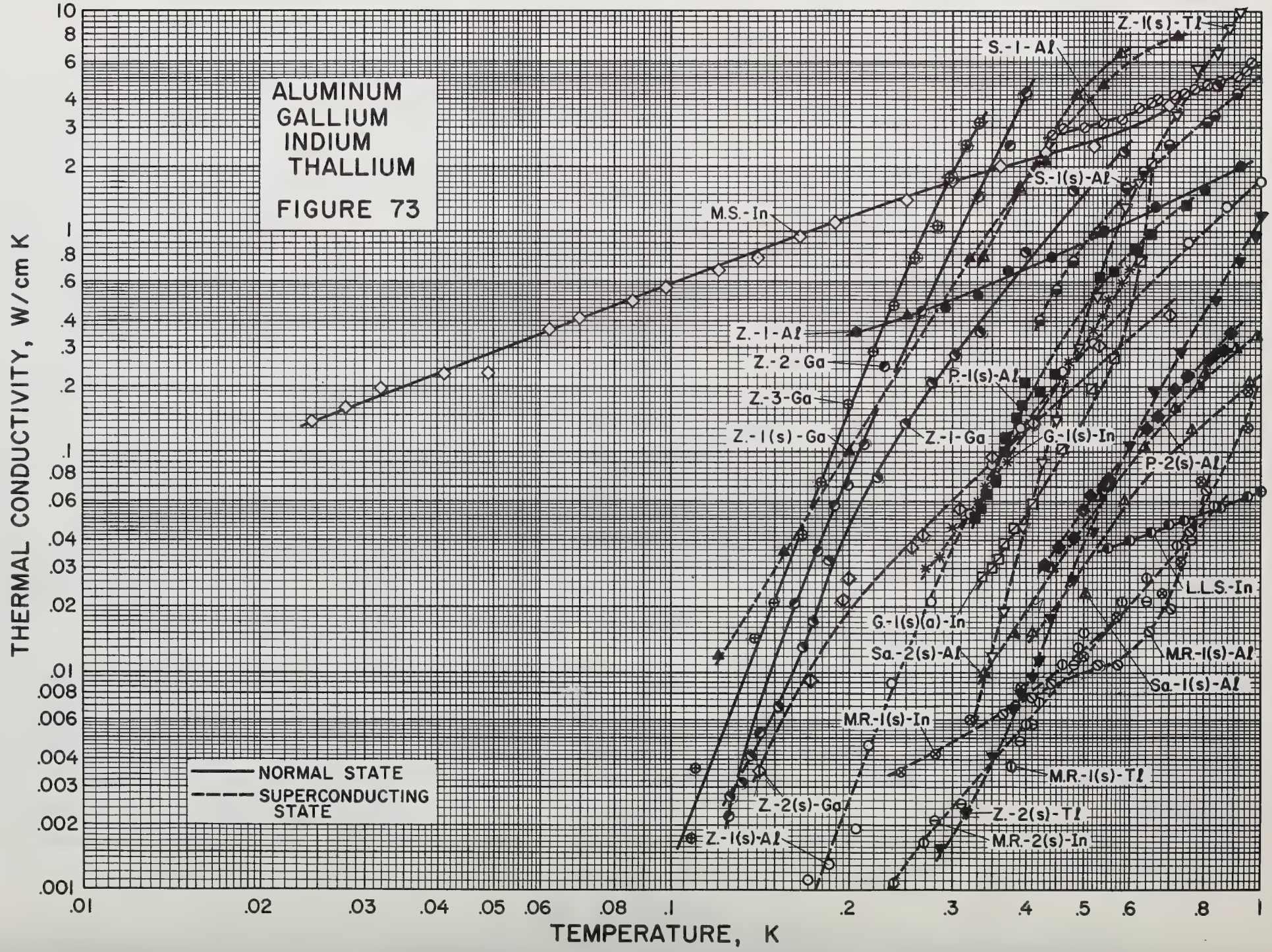
ALUMINUM
GALLIUM
INDIUM
THALLIUM
FIGURE 73
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
NORMAL STATE
SUPERCONDUCTING STATE
Z.-I(s)-Tl
S.-I-Al
S.-I(s)-Al
M.S.-In
Z.-I-Al
Z.-2-Ga
P.-I(s)-Al
Z.-3-Ga
Z.-I(s)-Ga
Z.-I-Ga
G.-I(s)-In
P.-2(s)-Al
L.L.S.-In
G.-I(s)(a)-In
Sa.-2(s)-Al
M.R.-I(s)-Al
Sa.-I(s)-Al
M.R.-I(s)-In
M.R.-I(s)-Tl
Z.-2(s)-Ga
Z.-2(s)-Tl
Z.-I(s)-Al
M.R.-2(s)-In

ALUMINUM, GALLIUM, INDIUM, and THALLIUM

(See FIGURE 73)

(temperatures below 1 K)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
		ALUMINUM		
M.R.-1(s)-Aℓ	. . . . .	. . . . .	A-1; B-1; C-1; D-3(2); E-6; F-4; G-3; N-3; Q-1.	K. Mendelssohn and C. A. Renton (1953).
P.-1(s), 2(s)-Aℓ; also see FIGURE 24d	#1: 0.001% Cu, Mg, and Si. #2: 0.068% Cu, 0.004% Fe, 0.003% Si, 0.001% Mn, 6 ppm(weight) Mg.	Cold-drawn. Measured in the superconducting (s) state. Also measured in the normal state above 1 K.	A-1; B-5; C-1; D-3(2); E-6; F-4; G-3; M-1; N-3.	L. Passell (1958).
Z.-1, 1(s)-Aℓ	0.01% impurities.	Specimen consisted of large crystals; annealed 4 hrs in vacuum at ~600°C. Measured in both the normal (in a longitudinal magnetic field of 0.01 T) and superconducting (s) states. Also measured another specimen of identical impurity concentration, with results 50% greater at 1 K. Graph of electronic thermal conductivity as a function of reduced temperature.	A-3; B-1; C-1; D-3(4); E-6; F-4; G-3; M-2; N-3; P-5; Q-1; S-3.	N. V. Zavaritskii (1958b).
Sa.-1(s), 2(s), 3(s)-Aℓ	#1: 0.3% Cu added impurity; RRR = 26. #2: Alcoa; nominally pure; RRR = 430. #3: Aluminum Industrie A.G.; RRR = 3660.	Work-hardened; machined; milled; folded into shape in pure aluminum template, annealed 2 hrs at 525°C. Transition temperatures of 1.149, 1.178, and 1.187 K, respectively. #3: originally zone refined. Measured in the superconducting (s) state. Graph of the ratio of the superconducting to normal thermal conductivity as a function of reduced thermal conductivity. #1: k = 40 at 0.843 K; k = 30.0 at 0.813 K.	A-1; B-3; C-1; D-3(2); E-5; F-4; G-2; M-2; N-3, 7; P-5; Q-1.	C. B. Satterthwaite (1962).
S.-1, 1(s)-Aℓ	Aluminum Laboratories; 99.999% pure; RRR(20) = 664.	Measured in both the normal (in magnetic field of 0.02 T) and superconducting (s) states. Graph of ratio of superconducting to normal thermal conductivity as a function of reduced temperature.	A-1; B-5; C-1; D-3(2); E-5; F-4; G-3; M-1; N-3; O-5; P-4, 5; Q-1.	J. K. N. Sharma (1967a) and (1967b); see also K. Mendelssohn, J. K. N. Sharma, and I. Yoshida (1965).

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ALUMINUM, GALLIUM, INDIUM, and THALLIUM (cont'd)

(See FIGURE 73) (temperatures below 1K)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
		GALLIUM		
Z. -1, 2, 3-Ga; See also FIGURE 25b	~0.001% impurities. #1: RRR(20) = 21,000. #2: RRR(20) = 14,000. #3: RRR(20) = 23,000.	Single crystals; grown by Kapitza method; diameter of 1.6 mm, length of 50 mm; transition temperature of 1.08 K. #1: grown along the c crystallographic direction. #2: grown along the b crystallographic direction. #3: grown along the a crystallographic direction. All directions within accuracy of 10°. Measured in longitudinal magnetic field up to 0.06 T. Graph of ratio of electronic thermal conductivity in superconducting state to the total thermal conductivity as a function of reduced temperature. Six other specimens also measured.	A-3; B-1; C-1; D-3(4); E-6; F-4; G-3; L-1, 2; M-1; N-3, 4; P-5.	N. V. Zavaritskii (1960a).
Z. -1(s), 2(s)-Ga	#1: 5×10^{-4}% impurity content; RRR(20) = 28,000. #2: 7.7×10^{-3}% impurity content; RRR(20) = 1900.	Single crystals; grown by Kapitza method; diameter of 1.1 mm and 1.2 mm, respectively. Measured in the superconducting (s) state. Three other specimens also measured, with intermediate results. Graphs of the ratio of the total thermal conductivity to the thermal conductivity in the superconducting state as a function of reduced transverse magnetic field. Measured in the intermediate state also.	A-3; B-1; C-1; D-3(4); E-6; F-4; G-3; M-4; N-3, 4; O-5, 6; P-5; Q-1.	N. V. Zavaritskii (1960b).
		INDIUM		
M. R. -1(s), 2(s)-In	Johnson, Matthey 4398; 99.993% pure.	#1: single crystal. #2: polycrystalline rod; circular cross section of 0.16 cm diameter. Measured in the superconducting (s) state.	A-1; B-1; C-1; D-3(2); E-6; F-4; G-3; M-1; N-3; P-4, 5; Q-1.	K. Mendelssohn and C. A. Renton (1953) and (1955).

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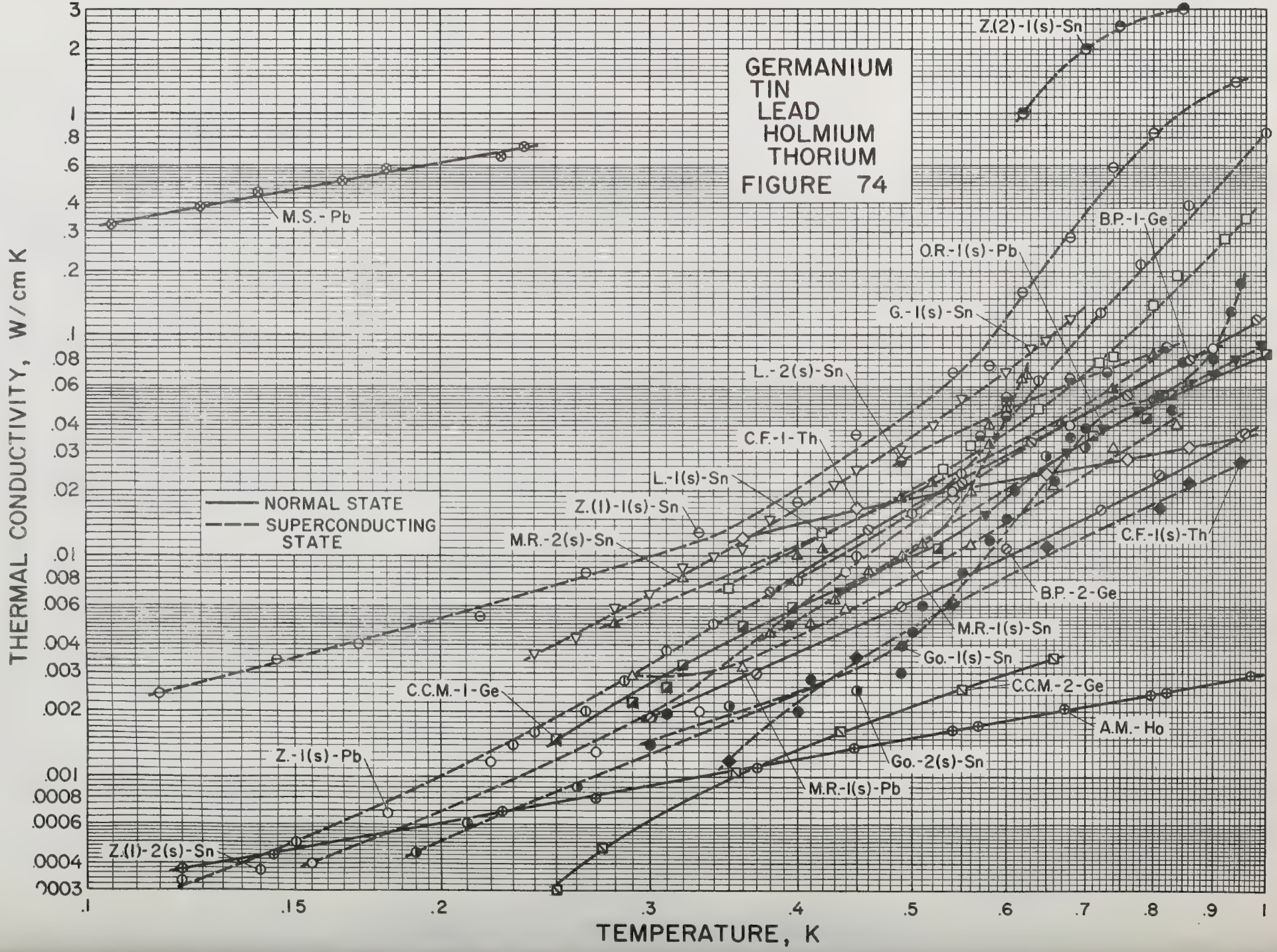
ALUMINUM, GALLIUM, INDIUM, and THALLIUM (cont'd)

(See FIGURE 73) (temperatures below 1 K)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
G. -1(s), 1(s)(a)-In	Johnson, Matthey 10281; 'spec. pure'.	Single crystals; cast from melt into Pyrex tubes; annealed in air at 120°C; diameter of 4.79 mm. #1: specimen surface treatment of electro-polish. #1(a): specimen surface then etched twice with 25% sulphuric acid, electro-polished, and etched again; diameter of 1.86 mm. Measurements made after each surface treatment, with intermediate results. Measured in the superconducting (s) state. Specimen of In-0.1% impurity also measured, with similar results.	A-1; B-1; C-1; D-3(2); E-6; F-4; G-3; M-2, 5; N-7; P-3, 4, 5.	G. M. Graham (1958).
M. S. -In	. . . . .	Measured in a longitudinal magnetic field of 0.035 T.	A-1; B-1; C-1; D-3(2); E-5, 6; F-4; G-3; M-1.	R. H. March and O. G. Symko (1965).
L. L. S. -In; also see FIGURE 47	American Smelting and Refining Co.; 1% Sn.	Annealed 6 months at 130°C. Measured in a longitudinal magnetic field of 0.09 T. Specimen then bent repeatedly at room temperature and remeasured, with results about 2% lower. Also measured above 1 K.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-3; M-2, 3; S-1, 5.	P. Lindenfeld, E. A. Lynton, and R. Soulen (1965).
		THALLIUM		
M. R. -1(s)-Tℓ	Johnson, Matthey 2544; 99.99% pure.	Circular cross section of 0.18 cm diameter.	A-1; B-1; C-1; D-3(2); E-6; F-4; G-3; M-1; N-3; P-4, 5; Q-1.	K. Mendelssohn and C. A. Renton (1953) and (1955).
Z. -1(s), 2(s)-Tℓ; also see FIGURE 25b	. . . . .	#1: rod axis inclined 30° to hexagonal axis; 1.6 mm diameter. #2: rod axis inclined 80° to hexagonal axis; 1.1 mm diameter. Measured in the superconducting (s) state. Two other specimens also measured, with intermediate results. Also measured above 1 K. Graph of the ratio of the superconducting to normal thermal conductivity states as a function of reduced temperature.	A-3; B-1; C-1; D-3(4); E-6; F-4; G-3; M-5; M-1, 3, 4; P-1, 5; Q-1; S-1, 5.	N. V. Zavaritskii (1961b).


GERMANIUM
TIN
LEAD
HOLMIUM
THORIUM
FIGURE 74
NORMAL STATE
SUPERCONDUCTING STATE
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
3
2
1
.8
.6
.4
.3
.2
.1
.08
.06
.04
.03
.02
.01
.008
.006
.004
.003
.002
.001
.0008
.0006
.0004
.0003
.1
.15
.2
.3
.4
.5
.6
.7
.8
.9
1
M.S.-Pb
Z.(2)-I(s)-Sn
B.P.-I-Ge
O.R.-I(s)-Pb
G.-I(s)-Sn
L.-2(s)-Sn
C.F.-I-Th
L.-I(s)-Sn
Z.(I)-I(s)-Sn
M.R.-2(s)-Sn
C.F.-I(s)-Th
B.P.-2-Ge
M.R.-I(s)-Sn
Go.-I(s)-Sn
C.C.M.-I-Ge
C.C.M.-2-Ge
A.M.-Ho
Z.-I(s)-Pb
Go.-2(s)-Sn
M.R.-I(s)-Pb
Z.(I)-2(s)-Sn

GERMANIUM, TIN, LEAD, HOLMIUM, and THORIUM

(See FIGURE 74)

(temperatures below 1 K)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
		GERMANIUM		
C. C. M. -1, 2-Ge; also see FIGURE 28d	Bell Telephone Laboratories. #1: In dopant, carrier concentration $1.9 \times 10^{14}/cm^3$. #2: Ga dopant, carrier concentration $2 \times 10^{18}/cm^3$.	Single crystals; p-type. Surfaces sand-blasted. #1: grown by zone process. Room temperature resistivity of 20-22 Ω-cm; inhomogenuities of 10% by resistivity measurements. Rod axis parallel to [111] crystal axis. #2: grown by Czochralski method. Resistivity of $6\text{-}12 \times 10^{-3}$ Ω-cm; inhomogenuities of 50%. Rod axis parallel to [100] crystal axis. Six other specimens also measured. Also measured above 1 K.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-3; O-5; P-2, 4; Q-1, 3; S-1.	J. A. Carruthers, J. F. Cochran, and K. Mendelssohn (1962).
B. P. -1, 2-Ge; also see FIGURE 28d	#1: impurity concentration of $5.4 \times 10^{13}/cm^3$. #2: P dopant, carrier concentration of $2.6 \times 10^{16}/cm^3$.	n-type. Specimen dimensions 4 x 4 x 24 mm; ground with powder; rod axis parallel to [100] crystal axis, perpendicular to growth axis. Two other specimens also measured. Also measured above 1 K.	A-1; B-1; C-1; D-3(2); E-5, 6; F-4; G-3; P-5, 9; Q-3.	B. L. Bird and N. Pearlman (1968).
		TIN		
Go. -1(s), 2(s)-Sn	'Spec. pure'.	Prepared by casting into glass tubes. #1: 1.3 mm diameter; #2: 0.7 mm diameter. Measured in the superconducting (s) state. Also measured one other "pure" specimen and two specimens with ~3%(weight) impurity. Graph of ratio of superconducting to normal thermal conductivity as a function of reduced temperature.	A-1; B-1; C-2; D-6(2); E-6; F-4; G-3.	B. B. Goodman (1953).
M. R. -1(s), 2(s)-Sn	Johnson, Matthey; 99.997% pure.	#1: single crystal; rectangular cross-section of 0.16 x 0.24 cm. #2: polycrystalline rod. Measured in the superconducting (s) state.	A-1; B-1; C-1; D-3(2); E-6; F-4; G-3; M-1; N-3; P-4, 5; Q-1.	K. Mendelssohn and C. A. Renton (1953) and (1955).

GERMANIUM, TIN, LEAD, HOLMIUM, and THORIUM (cont'd)

(See FIGURE 74)

(temperatures below 1 K)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
L. -1(s), 2(s)-Sn; also see FIGURE 29b	Johnson, Matthey 4600. #1: "spectroscopically pure". #2: 0.35% In.	Single crystals; cast in glass tubes; #1 was recrystallized before removing glass; lightly etched. #1: rod axis parallel to tetragonal axis. #2: rod axis inclined 82° to tetragonal axis. Measured in the superconducting (s) state. Graph of ratio of the electronic thermal conductivity in the superconducting to normal state as a function of reduced temperature. Also measured several other specimens. Also measured above 1 K.	A-1; B-1; C-1; D-3(2); E-5, 6; F-4; G-3; M-1, 2; N-3, 4; O-5; P-4, 5; Q-1; S-1, 5.	S. J. Laredo (1955).
G. -1(s)-Sn	Johnson, Matthey 5606; 'spec. pure'.	Three large crystals; cast from melt into Pyrex tubes; annealed in air at 120°C; diameter of 2.82 mm. Measured in superconducting (s) state. Two other specimens also measured after surface treatment.	A-1; B-1; C-1; D-3(2); E-6; F-4; G-3; M-2, 5; N-7; P-3, 4, 5.	G. M. Graham (1958).
Z. (1)-1(s), 2(s)-Sn	0.002% impurity.	Single crystals; cast in thin-walled capillary, diameter of 1.75 mm. #1: polished surface; rod axis inclined 45° to (001) direction. #2: rough surface; rod axis inclined 70° to (001) direction. Measured in the superconducting (s) state. Two other specimens also measured, with intermediate results.	A-3; B-1; C-1; D-3(4); E-6; F-4; G-3; M-4; N-3; O-5; P-5; Q-1; S-3.	N. V. Zavaritskii (1958a) and (1960b).
Z. (2)-1(s)-Sn; also see FIGURE 29c	. . . . .	Rod axis parallel to (001) direction. Measured in the superconducting (s) state.	A-3; B-1; C-1; D-3(4); E-6; F-4; G-3; M-5; N-1, 3, 4; P-1, 5; Q-1; S-1, 5.	N. V. Zavaritskii (1961b).
		LEAD		
O. R. -1(s)-Pb	Goodlass Wall and Lead Industries; 99.998% pure Tadanac lead.	Single crystal. Measured in the superconducting (s) state. Measured change of thermal resistivity in magnetic field in normal, intermediate, and superconducting state. Also measured above 1 K; see LEAD in "Elements" section.	A-1; B-1; C-1; D-3(2); E-6; F-4; G-3; N-3.	J. L. Olsen and C. A. Renton (1952).

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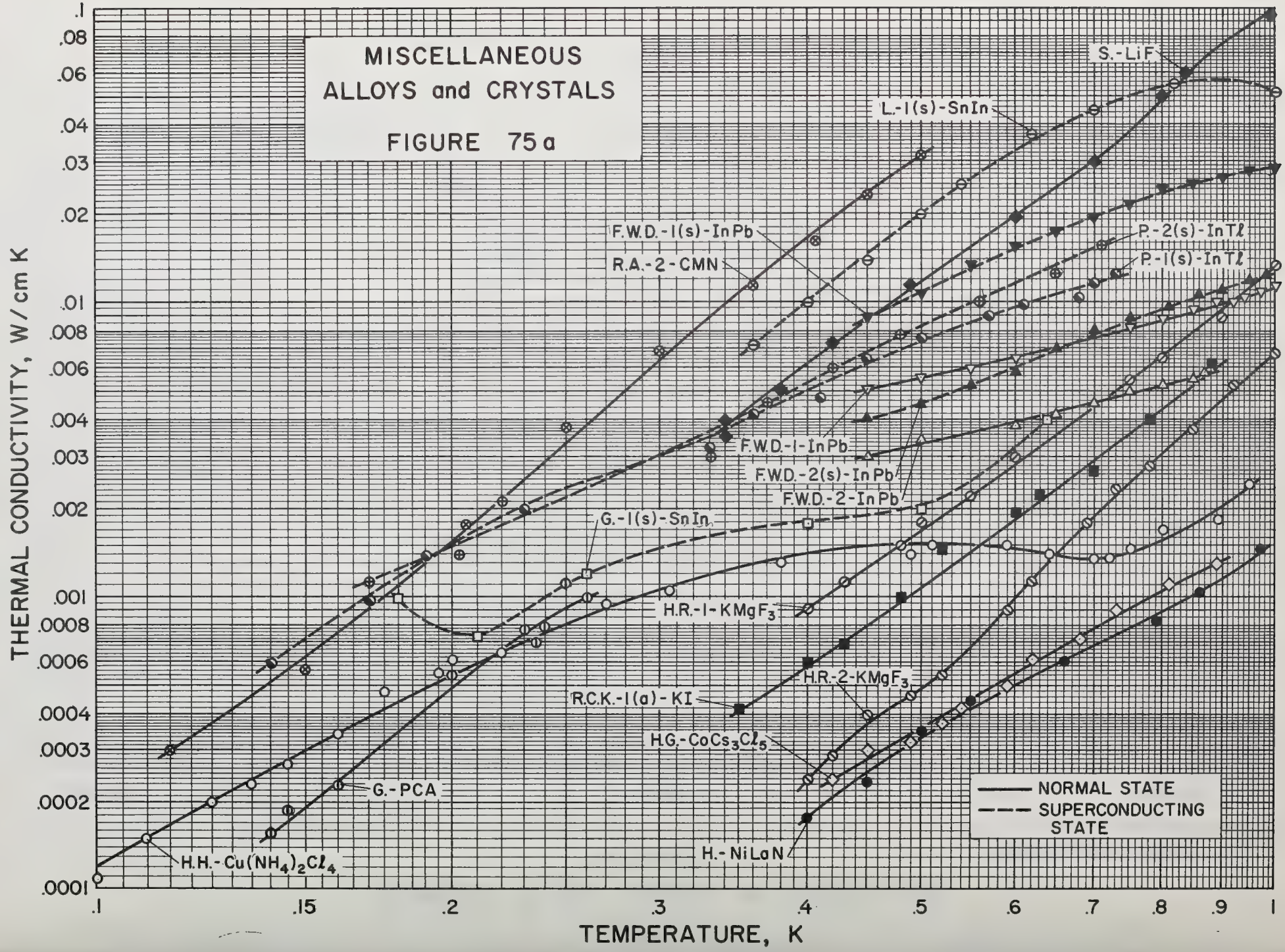
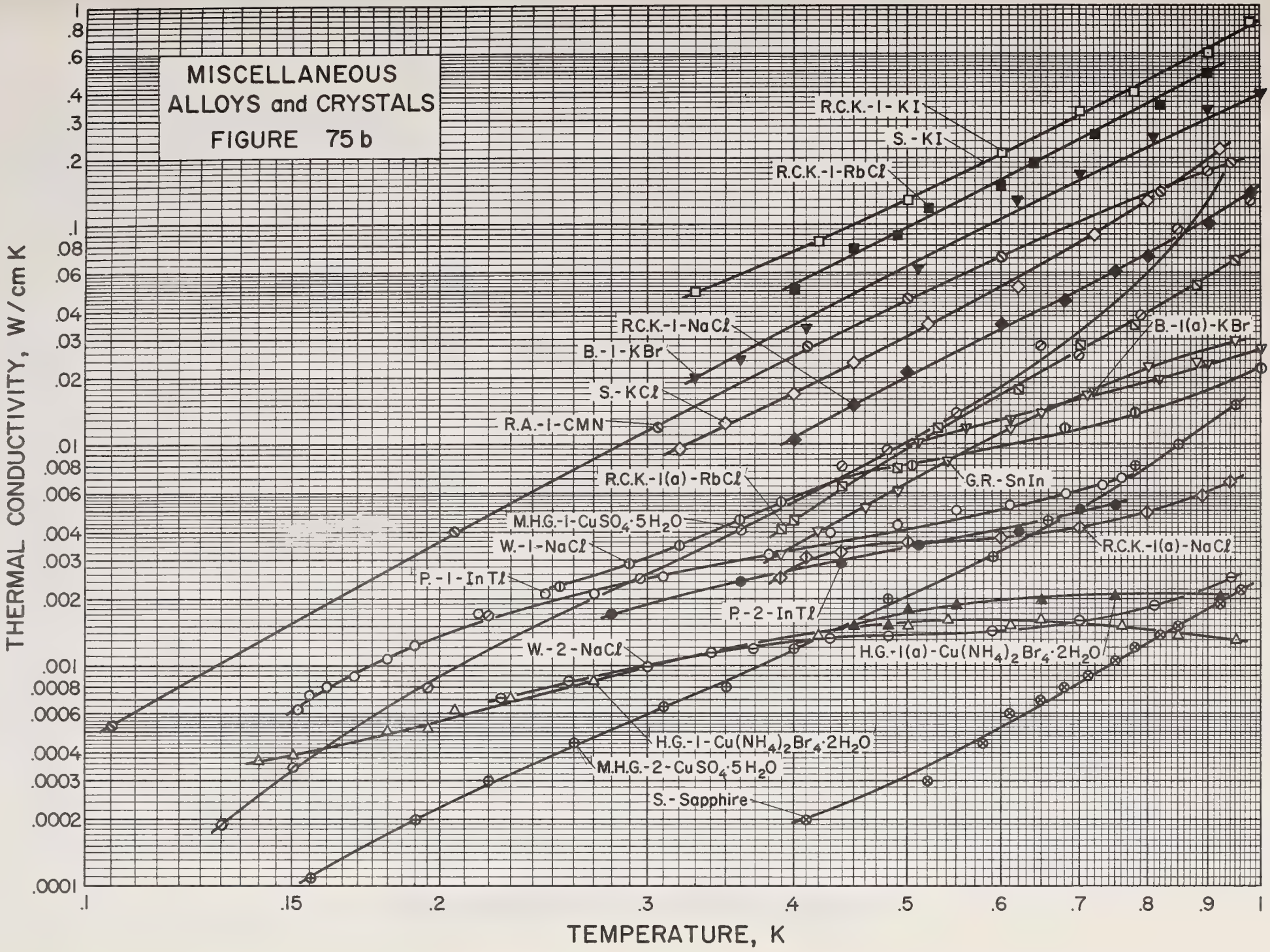
GERMANIUM, TIN, LEAD, HOLMIUM, and THORIUM (cont'd)

(See FIGURE 74) (temperatures below 1 K)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
M.R.-1(s)-Pb	Goodlass Wall and Lead Industries; 99.998% pure Tadanac lead.	Measured in the superconducting (s) state. Rectangular cross-section of 0.13 x 0.20 cm. Also measured with no magnetic shield, with similar results.	A-1; B-1; C-1; D-3(2); E-6; F-4; G-3; M-1; N-3; P-4, 5; Q-1.	K. Mendelssohn and C. A. Renton (1955).
Z.-1(s)-Pb	. . . . .	Single crystal; cast in vacuum in thin-walled glass capillaries; etched; length of 50 mm, diameter of 1.3 mm. Measured in the superconducting (s) state.	A-3; B-1; C-1; D-3(4); E-6; F-4; G-3; M-4; N-3, 4; O-5, 6; P-5; Q-1; S-3.	N. V. Zavaritskii (1960b).
M.S.-Pb	Koch-Light.	Measured in a longitudinal magnetic field of 0.1 T.	A-1; B-1; C-1; D-3(2); E-5, 6; F-4; G-3; M-1.	R. H. March and O. G. Symko (1965).
		HOLIUM		
A.M.-Ho	99.9% pure.	Spark-cut. Individual crystals $\sim 6 \times 10^{-5}$ cm^3 in volume.	A-1; B-2; C-1; D-3(2); E-5, 6; F-4; G-2; M-1; S-1, 5.	A. C. Anderson and M. E. Malinowski (1970).
		THORIUM		
C.F.-1, 1(s)-Th; also see FIGURE 36b	"Nominally pure".	Prepared by electrotransport method under 10^{-9} Torr. Grain size of 0.1 mm. Measured in both the normal (in magnetic fields up to 0.02 T) and superconducting (s) states. T_c = 1.360 K. Also measured two specimens of Th doped with 0.1 and 0.2 (atomic) % Gd. Also measured above 1 K.	A-1; B-1; C-1; D-3(2); E-3, 5, 6; F-4; G-2; M-1, 6; N-3; P-3; Q-1; S-5.	R. L. Cappellet and D. K. Finnemore (1969).


MISCELLANEOUS
ALLOYS and CRYSTALS
FIGURE 75a
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
.1
.08
.06
.04
.03
.02
.01
.008
.006
.004
.003
.002
.001
.0008
.0006
.0004
.0003
.0002
.0001
.1
.15
.2
.3
.4
.5
.6
.7
.8
.9
1
S.-LiF
L.-I(s)-SnIn
F.W.D.-I(s)-InPb
R.A.-2-CMN
P.-2(s)-InTl
P.-I(s)-InTl
F.W.D.-I-InPb
F.W.D.-2(s)-InPb
F.W.D.-2-InPb
G.-I(s)-SnIn
H.R.-I-KMgF3
H.R.-2-KMgF3
R.C.K.-I(a)-KI
H.G.-CoCs3Cl5
G.-PCA
H.H.-Cu(NH4)2Cl4
H.-NiLaN
NORMAL STATE
SUPERCONDUCTING STATE


MISCELLANEOUS
ALLOYS and CRYSTALS
FIGURE 75 b
THERMAL CONDUCTIVITY, W/cm K
TEMPERATURE, K
R.C.K.-I-KI
S.-KI
R.C.K.-I-RbCl
R.C.K.-I-NaCl
B.-I-KBr
S.-KCl
R.A.-I-CMN
B.-I(a)-KBr
G.R.-SnIn
R.C.K.-I(a)-RbCl
M.H.G.-I-CuSO4·5H2O
W.-I-NaCl
R.C.K.-I(a)-NaCl
P.-I-InTl
P.-2-InTl
W.-2-NaCl
H.G.-I(a)-Cu(NH4)2Br4·2H2O
H.G.-I-Cu(NH4)2Br4·2H2O
M.H.G.-2-CuSO4·5H2O
S.-Sapphire

MISCELLANEOUS ALLOYS and IONIC CRYSTALS

(See FIGURES 75a and 75b) (temperatures below 1 K)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
		INDIUM ALLOYS		
P. -1, 1(s), 2, 2(s)-In-Tℓ	#1: 85% In-15% Tℓ. #2: 80% In-20% Tℓ.	#1: single crystal. Also a polycrystal of similar composition was measured. Measured in both the normal (in a transverse mangetic field of 0.008 T) and superconducting (s) states.	A-1; B-1; C-1; D-3(2); E-6; F-4; G-3.	N. E. Phillips (1955).
F. W. D. -1, 1(s), 2, 2(s), -In-Tℓ; see also FIGURE 47	#1: In-4.05% Pb. #2: In-7.31% Pb.	Measured in both the normal and superconducting (s) states. Also measured above 1 K.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-3; M-1; N-3; O-9; P-2, 4; Q-1.	G. T. Fox, M. W. Wolfmeyer, and J. R. Dillinger (1969).
		TIN ALLOYS		
G. -1(s)-Sn-In	Sn + 3% (weight) In.	Specimen diameter of 2.8 mm. Measured in the superconducting (s) state. Also measured another specimen of similar composition.	A-1; B-1; C-2; D-6(2); E-6; F-4; G-3; M-2; P-5; Q-1.	B. B. Goodman (1953).
L. -1(s)-Sn-In	Johnson, Matthey 4600 Sn, with 3.10% (weight) In impurity.	Single crystal; rod axis inclined 73° to tetragonal axis.	A-1; B-1; C-1; D-3(2); E-6; F-4; G-3.	S. J. Laredo (1955).
Gr. -Sn-In	Sn-3 In.	Annealed 14 days in vacuum at 320°C; specimen diameter of 0.875 mm; etched; rod axis inclined 80° to tetrad axis. Three other alloys with different surface treatment and diameter also measured.	A-1; B-1; C-1; D-3(2); E-6; F-4; G-3; M-2, 5; N-7; P-3, 4, 5, 12.	G. M. Graham (1958).
		LITHIUM IONIC CRYSTAL		
S. -LiF; also see FIGURE 57c	Harshaw Chemical Co.; undoped.	Sandblasted. Also measured above 1 K.	A-1; B-1; C-1; D-3(2); E-5, 6; F-4; G-2; O-3; P-2, 5.	W. D. Seward (1965).

MISCELLANEOUS ALLOYS and IONIC CRYSTALS (cont'd)

(See FIGURES 75a and 75b)

(temperatures below 1 K)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
		SODIUM IONIC CRYSTALS		
W.-1, 2-NaCℓ	Prepared from "pure" NaCℓ, with OH^- concentration of $7 \times 10^{14}/cm^3$, and AgCℓ. #1: NaCℓ + 5×10^{-5} colloidal silver. #2: NaCℓ + 8×10^{-4} colloidal silver.	NaCℓ and small pellet of AgCℓ mixed together by precipitation. Another specimen of intermediate concentration of colloidal silver also measured, with intermediate results. #2: same specimen as Wo.-1(b)-NaCℓ as seen on SODIUM IONIC CRYSTALS Table.	A-1; B-1; C-1; D-3(2); E-5, 6; F-4; G-2.	D. Walton (1967).
R.C.K.-1(a)-NaCℓ; see also FIGURE 58c	#1(a): NaCℓ: doped with NaOH, 4 ppm OH^-.	Cleaved from boule; sandblasted. Also measured several other specimens. Also measured above 1 K.	A-1; B-1; C-1; D-2(2); E-6; F-4; G-2; O-2, 3; P-5, 7, 8.	R. L. Rosenbaum, C.-K Chau, and M. V. Klein (1969).
		POTASSIUM IONIC CRYSTALS		
. . . . .	. . . . .	Preliminary imprecise results given for potassium chromium alum near 0.2 K. Result also given for iron ammonium alum near 0.1 K.	. . . . .	N. Kürti, B. V. Rollin, and F. Simon (1936).
G.-PCA	Potassium chrome alum.	Single crystal; octagonal cross-section, 15 mm across; rod axis parallel to cubic axis.	A-3; B-1; C-5; D-6; E-6; F-4; G-3; O-5; P-4.	C. G. B. Garrett (1950).
S.-KCℓ, KI; also see FIGURE 58c	High purity.	Sandblasted. Also measured two specimens of KCℓ doped with CN. Also measured above 1 K.	A-1; B-1; C-1; D-3(2); E-5, 6; F-4; G-2; O-3; P-2, 5, 7.	W. D. Seward (1965).
B.-1, 1(a)-KBr; also see FIGURE 58c	Reagent-grade material. #1: pure KBr. #1(a): KBr doped with Li, concentration of $1.8 \times 10^{19}/cm^3$.	Prepared by seed-pulling under halogen atmosphere; no NO_2^-, CN^-, or OH^- observed; cleaved along {100} planes; sandblasted. Also measured one other specimen with intermediate concentration, with intermediate results. Also measured KCℓ specimens doped with Li. Also measured above 1 K.	A-1; B-1; C-1; D-1(2); E-4, 8; F-4; G-3; O-3, 9; P-2, 5, 7, 8.	F. C. Baumann, J. P. Harrison, R. O. Pohl, and W. D. Seward (1967).
R.C.K.-1, 1(a)-KI; also see FIGURE 58c	#1: pure KI. #1(a): KI, doped with KOH, 90 ppm OH^-.	Also measured undoped and doped specimens of KCℓ and KBr. Also measured above 1 K.	A-1; B-1; C-1; D-2(2); E-6; F-4; G-2; O-2, 3; P-5, 7, 8.	R. L. Rosenbaum, C.-K. Chau, and M. V. Klein (1969).

MISCELLANEOUS ALLOYS and IONIC CRYSTALS (cont'd)

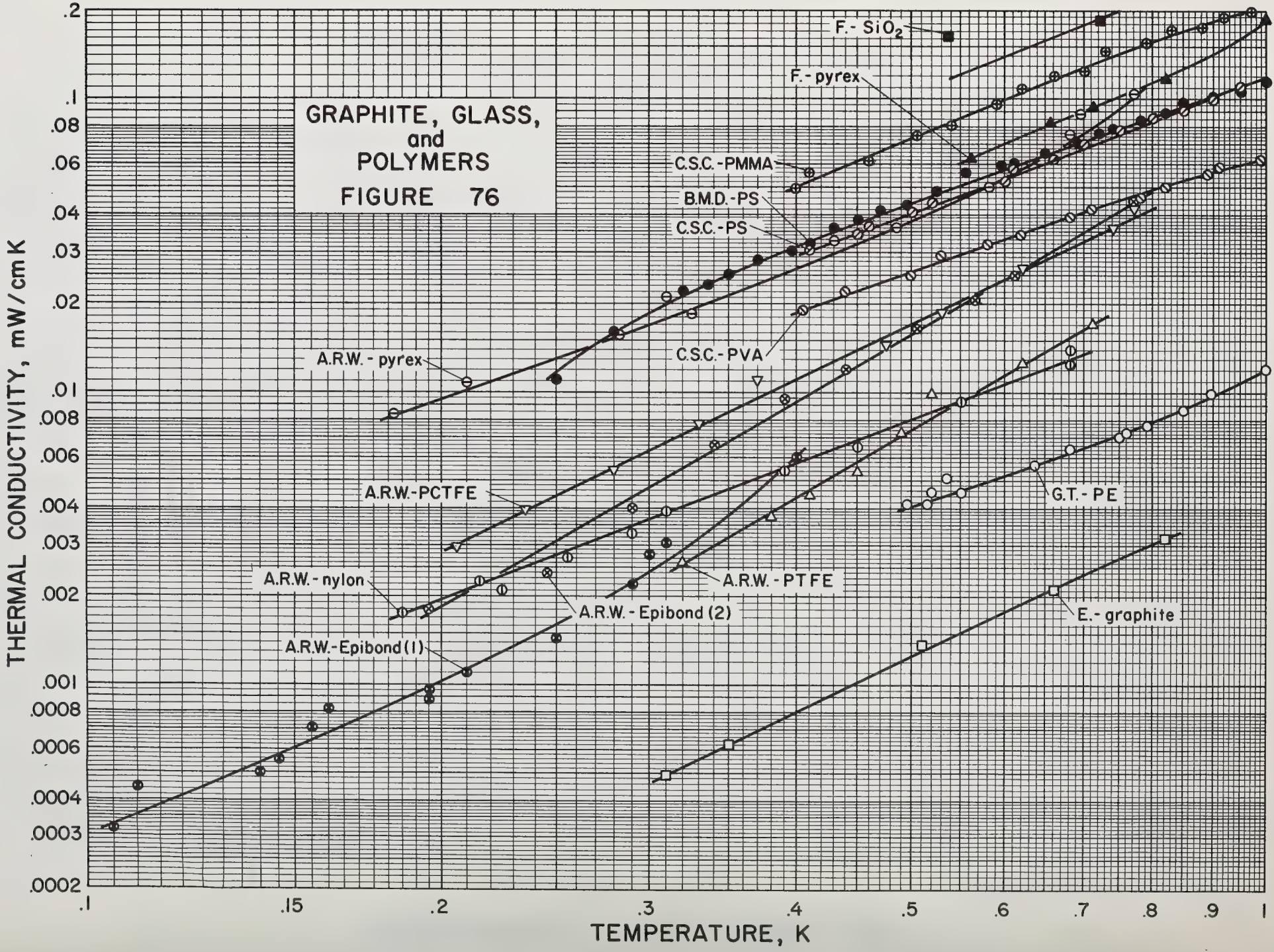
(See FIGURES 75a and 75b) (temperatures below 1 K)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
H. R. -1, 2- $KMgF_3$	British Drug Houses; doped with Ni^{2+}. #1: 0.5(atomic) Ni. #2: 3.0 Ni.	Single crystals; grown from melt using zone-refined KF and MgF_2 and NiF_2; annealed 18-24 hrs at 1230 K in He, cooled slowly for 30 hrs; rod axis parallel to ⟨100⟩ axis. Also measured in longitudinal magnetic field of up to 5 T. Also measured above 1 K.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-3; O-5, 9; P-2, 5, 7, 10.	R. T. Harley and H. M. Rosenberg (1970).
		RUBIDIUM IONIC CRYSTALS		
R. C. K. -1, 1(a)- $RbC\ell$; also see FIGURE 58c	#1: pure $RbC\ell$. #1(a): $RbC\ell$, doped with RbOH, 480 ppm OH.	Also measured above 1 K.	A-1; B-1; C-1; D-2(2); E-6; F-4; G-2; O-2, 3; P-5, 7, 8.	R. L. Rosenbaum, C. -K. Chau, and M. V. Klein (1969).
		LANTHANUM IONIC CRYSTAL		
. . . . .	. . . . .	LMN: lanthanum magnesium nitrate; single crystal; values 30% lower than R. A. -1-CMN at 0.04 K, and 0% difference at 1 K.	. . . . .	J. E. Robichaux and A. C. Anderson (1970).
		COBALT IONIC CRYSTAL		
H. G. -$CoCs_3C\ell_5$	Co salt.	Three-dimensional Ising antiferromagnet; T_c = 0.53 K. Measured in zero magnetic field. Measured in transverse magnetic field of 1 T, with similar results. Also measured above 1 K; see COBALT DIELECTRIC CRYSTAL Table.	A-1; B-1; C-1; D-3(2); G-3; Q-5; R-2.	J. N. Haasbroek and A. S. M. Gieske (1970); see also Haasbroek (1971).
		COPPER IONIC CRYSTALS		
M. H. G. -1, 2- $CuSO_4 \cdot 5H_2O$	. . . . .	Specimens cut from single crystal; ground to 3 x 3 x 20 mm. #1: rod axis parallel to a-axis. #2: rod axis perpendicular to a-axis. Also measured specimen with rod axis inclined 45° to a-axis.	A-1; B-1; C-1; D-3(2); G-3; O-6; P-5, 10.	A. R. Miedema, J. N. Haasbroek, and F. W. Gorter (1965).

MISCELLANEOUS ALLOYS and IONIC CRYSTALS (cont'd)

(See FIGURES 75a and 75b) (temperatures below 1 K)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
H. G. -1, 1(a)- $Cu(NH_4)_2Br_4 \cdot 2H_2O$	Cu salt.	Three-dimensional Heisenberg ferromagnet; T_c = 1.75 K. #1: measured in zero magnetic field. #1(a): measured in transverse magnetic field of 1.1 T. Also measured above 1 K.	A-1; B-1; C-1; D-3(2); G-3; Q-5; R-2.	J. N. Haasbroek and A. S. M. Gieske (1970); see Haasbroek (1971).
H. H. - $Cu(NH_4)_2Cl_4$	. . . . .	Cut from single crystal; grown from aqueous solution; ferromagnet; T_c = 0.70 K; rod axis parallel to c-axis; specimen size of 2.3 x 2.7 x 17.7 mm.	A-1; B-1; C-1; D-3(2); G-2; P-7, 10; Q-5; R-2.	J. N. Haasbroek and W. J. Huiskamp (1970); see also Haasbroek (1971).
		NICKEL IONIC CRYSTAL		
H. -NiLaN	$Ni_3La_2(NO_3)_{12} \cdot 24H_2O$.	Also measured in magnetic fields up to 1.1 T. Also measured up to 5 K. T_c = 0.393 K.	A-1; B-1; C-1; D-3(2); E-3; G-2; Q-5; R-2.	J. N. Haasbroek (1971).
		CERIUM IONIC CRYSTAL		
R. A. -1, 2-CMN	American Potash and Chemical Corp.; 99.9999 $CeNO_3$, $MgNO_3$ from Mallinckrodt Chemical Works. #1: 100 ppm (atomic) Cr, 80 ppm V, 70 ppm Cu, 40 ppm Ni, 20 ppm Fe and Mn, 6 ppm La, and 5 ppm Pr. #2: CMN doped with 0.8 (atomic) Pr.	CMN: cerium magnesium nitrate; doubly recrystallized; transparent and optically perfect. #1: "pure". #2: doped with Pr. Specimen size of 1 cm width, 2-4 cm length; rod axis perpendicular to hexagonal axis. Also measured 14 other specimens.	A-1; B-1; C-3; D-3(2); E-6; F-4; G-3; O-6; P-4, 6, 7, 10, 12.	J. E. Robichaux and A. C. Anderson (1970).
		SAPPHIRE		
S. -sapphire	. . . . .	Single crystal.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-3.	J. K. N. Sharma (1967a).


GRAPHITE, GLASS, and POLYMERS
FIGURE 76
THERMAL CONDUCTIVITY, mW/cm K
TEMPERATURE, K
.2
.1
.08
.06
.04
.03
.02
.01
.008
.006
.004
.003
.002
.001
.0008
.0006
.0004
.0003
.0002
.1
.15
.2
.3
.4
.5
.6
.7
.8
.9
1
F.- SiO2
F.- pyrex
C.S.C.-PMMA
B.M.D.-PS
C.S.C.-PS
C.S.C.-PVA
A.R.W.- pyrex
A.R.W.-PCTFE
A.R.W.- nylon
A.R.W.- Epibond (2)
A.R.W.- Epibond (1)
A.R.W.- PTFE
G.T.- PE
E.- graphite

GRAPHITE, POLYMERS, and GLASS

(See FIGURE 76) (temperatures below 1 K)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
A. R. W. -nylon, PTFE, PCTFE pyrex, Epibond(1), Epibond(2)	Epibond(2): Furane Plastics; diglycidal ether of bisphenol mixed 4:1 with powdered Bentonite clay.	Machined directly from stock material. Nylon: polyamide. PTFE: polytetrafluoroethylene (Teflon). PCTFE: polychlorotrifluoroethylene (Kel-F). Epibond(1): Epibond 100 A; diglycidal ether of bisphenol; solid. Epibond(2): Epibond 104; diglycidal ether of bisphenol.	A-1; B-1; C-1; D-3(2); E-6; F-4; G-3; O-5; P-4.	A. C. Anderson, W. Reese, and J. C. Wheatley (1963).
E. -graphite; also see FIGURE 26e	Union Carbide; AGOT nuclear grade.	Extruded; measurements were to the extrusion direction. Also measured above 1 K.	A-1; B-1; C-1; D-3(2); G-3.	D. O. Edwards, R. E. Sarwinski, P. Seligmann, and J. T. Tough (1968).
F. -pyrex; also see FIGURE 67b	80.9 (weight) % SiO_2, 12.19 B_2O_3, 4.24 Na_2O, 2.28 Al_2O_3, 0.11 ZrO_2, 0.02 K_2O, 0.014 Fe^{+2}, <0.01 Li_2O, 0.006 ± 1 Fe^{+3}.	7740 Pyrex; measured in zero magnetic field. Also measured above 1 K.	A-1; B-1; C-1; D-3(2); F-4; G-3.	R. A. Fisher, G. E. Brodale, E. W. Hornung, and W. F. Giaque (1968).
F. -SiO_2; also see FIGURE 67b	Englehard Industries; iron free.	SiO_2 glass; annealed 3 hrs at 1000°C; no trace of strains; density of 2.202 g/cm^3. Also measured above 1 K.	A-1; B-1; C-1; D-3(2); E-5; F-4; G-3.	R. A. Fisher, G. E. Brodale, E. W. Hornung, and W. F. Giaque (1969).
B. M. D. -PS	Stock.	PS: polystyrene. Also measured specimen of polystyrene with 40% crosslinking; values were 20% greater at 1 K and 0% at 0.2 K. Also measured polystyrene specimen with 20% crosslinking, with intermediate results.	A-1; B-1; C-1; D-3(2); F-4; G-3; P-4.	B. L. Berman, R. P. Madding, and J. R. Dillinger (1969).
G. T. -PE; see also FIGURE 68b	Commercial.	PE: polyethylene; density of 0.947 g/cm^3; fractional crystallinity ~ 65%. Also measured above 1 K.	A-1; B-1; C-1; D-3(4); E-5; G-3; O-9; P-4; Q-2.	M. Giles and C. Terry (1969).

GRAPHITE, POLYMERS, and GLASS (cont'd)

(See FIGURE 76)

(temperatures below 1 K)

CURVE	SAMPLE SOURCE COMPOSITION (%)	REMARKS	CODE	REFERENCE
C.S.C.-PMMA, PS, PVA; also see FIGURE 68b	PMMA: E. I. duPont. PVA: Shawinigan Resins.	PMMA: polymethyl methacrylate (Lucite II); average molecular weight of 1.6×10^5; density of 1.185 g/cm^3. PS: polystyrene; average molecular weight of 1.792×10^5; density of 1.04 g/cm^3. PVA: polyvinyl acetate; density of 1.20 g/cm^3. Also measured above 1 K.	A-1; B-1; C-1; D-3(2); F-4; G-3; O-9; P-4, 7; S-3.	C. L. Choy, G. L. Salinger, and Y. C. Chiang (1970).

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4. Detailed Index of Specific Materials

Material	Table heading	Figure number
Admiralty metal	Copper Alloys	
Advance	Cu-Ni Alloys	
Almandite	Minerals	63b
Alpha brass	Copper Alloys	43a, c
Alumina	Alumina and Sapphire Crystals	64a, b, c
Aluminum	Aluminum	24a, b, 73
A 13 alloy	Aluminum Alloys	
Adataloy	do	
Alar	do	
00.5	Aluminum Alloys	
00.12	do	
Alcan		
A 143	Aluminum Alloys	
A 320	do	
B 515	do	
143	do	
162	do	
164	do	
236	do	
285	do	
350	do	
432	do	
575	do	
Allcast 60	do	
Alloy	do	
3003-F	Aluminum Alloys	46
5052-O	do	46
5083-O	do	46
5154-O	do	46
6063T-O	do	46
Alufont 3	do	
Alumina	Alumina and Sapphire Crystals	64a, b, c
Aluminum alloy	do	
A 108	Aluminum Alloys	
A 132	do	
A 380	do	
A 612	do	
A 750	do	
B 214	do	
B 750	do	
C 113	do	
C 612	do	
EC	do	
F 214	do	
13	do	
21	do	
50 S	do	
112	do	
113	do	
138	do	
195	do	
214	do	
218	do	
220	do	
236	do	
319	do	
Aluminum alloy (cont.)		
	Aluminum Alloys	
333	do	
356	do	
360	do	
363	do	
364	do	
380	do	
384	do	
750	do	
755	do	
1060	do	
2011	do	
2018	do	
2024	do	
2218	do	
2219	do	
3004	do	
5005	do	
5050	do	
5052	do	
5056	do	
5083	do	
5086	do	
5154	do	
5357	do	
5454	do	
5456	do	
5457	do	
6066	do	
6101	do	
6161	do	
6351	do	
7001-T6	do	
7005	do	
7075	do	
7079	do	
7178	do	
	Aluminum Alloys	
Alusil	do	
Alusiloy 1	do	
AMS	do	
4035	Aluminum Alloys	
4037	do	
4088	do	
4120	do	
4152	do	
4231	do	
Apex	do	
Z 39	Aluminum Alloys	
Z 39-11	do	
Z 50	do	
28	do	
36	do	
39	do	
39.11	do	
400	do	
418	do	

4. Detailed Index of Specific Materials—Continued

Material	Table heading	Figure number
	Aluminum Alloys	
ASTM alloy	---------do-------	
GR 40 A	Aluminum Alloys	----------
SC 114 A	---------do-------	----------
SG 84 A	---------do-------	----------
SG 84 B	---------do-------	----------
SG 100 A-B	---------do-------	----------
SN 122 A	---------do-------	----------
ZG 32 A	---------do-------	----------
ASTM	---------do-------	
B 26-52 T alloy ZG 61 B	---------do-------	----------
B 26 alloy C4 A	---------do-------	----------
B 26 alloy CN 42 A	---------do-------	----------
B 26 alloy G4 A	---------do-------	----------
B 26 alloy GS 42 A	---------do-------	----------
B 26 alloy S5 A	---------do-------	----------
B 26 alloy S5 B	---------do-------	----------
B 26 alloy SC 21	---------do-------	----------
B 26 alloy SC 51 A	---------do-------	----------
B 26 alloy SC 64 A	---------do-------	----------
B 26 alloy SG 1	---------do-------	----------
B 26 alloy SG 70 A	---------do-------	----------
B 26 alloy ZG 61 A	---------do-------	----------
B 26 alloy ZG 61 B	---------do-------	----------
B 26 C1	---------do-------	----------
B 26 C5 21	---------do-------	----------
B 26 G 10 A	---------do-------	----------
B 85 60 alloy SC 114 A	---------do-------	----------
B 85 68 A	---------do-------	----------
B 85 alloy S 5 C	---------do-------	----------
B 85 alloy S 12 A	---------do-------	----------
B 85 alloy S 12 B	---------do-------	----------
B 85 alloy SC 84 A	---------do-------	----------
B 85 alloy SC 84 B	---------do-------	----------
B 85 alloy SG 2	---------do-------	----------
B 85 alloy SG 3	---------do-------	----------
B 108 alloy CN 42 A	---------do-------	----------
B 108 alloy CS 42 A	---------do-------	----------
B 108 alloy CS 104 A	---------do-------	----------
B 108 alloy S5 A	---------do-------	----------
B 108 alloy S5 B	---------do-------	----------
B 108 alloy SC 8	---------do-------	----------
B 108 alloy SC 21	---------do-------	----------
B 108 alloy SC 51 A	---------do-------	----------
B 108 alloy SC 64 A	---------do-------	----------
B 108 alloy SC 64 B	---------do-------	----------
B 108 alloy SC 103 A	---------do-------	----------
B 108 alloy SG 1	---------do-------	----------
B 108 alloy SG 70 A	---------do-------	----------
B 108 alloy SN 122 A	---------do-------	----------
B 178-54 T alloy GM 40 A	---------do-------	----------
B 179 alloy 68 A	---------do-------	----------
B 179 alloy CS 72 A	---------do-------	----------
B 179 alloy CS 104 A	---------do-------	----------
B 179 alloy S 12 A	---------do-------	----------
B 179 alloy S 12 B	---------do-------	----------
ASTM alloy (cont.)		
	Aluminum Alloys	
B 179 alloy SC 51 A	---------do-------	----------
B 179 alloy SC 84 A	---------do-------	----------
B 179 alloy ZG 61 B	---------do-------	----------
B 179 G 10 A	---------do-------	----------
B 179-S 12 A	---------do-------	----------
B 179 SC 84 A	---------do-------	----------
B 179 SC 84 B	---------do-------	----------
B 209	---------do-------	----------
B 209-54 T alloy GM 40 A	---------do-------	----------
B 209 alloy CG 42 A	---------do-------	----------
B 209 alloy GR 20 A	---------do-------	----------
B 209 alloy MG 11 A	---------do-------	----------
B 210	---------do-------	----------
B 210 alloy GR 1	---------do-------	----------
B 210 alloy GR 20 A	---------do-------	----------
B 211 alloy CB 60 A	---------do-------	----------
B 211 alloy CP 21	---------do-------	----------
B 234	---------do-------	----------
B 235	---------do-------	----------
B 241	---------do-------	----------
B 247	---------do-------	----------
B 247-57 T alloy SG 11 A	---------do-------	----------
B 247 alloy CN 42 C	---------do-------	----------
B 247 alloy CN 42 D	---------do-------	----------
B 274 alloy MG 11 A	---------do-------	----------
B 285	---------do-------	----------
B 307	---------do-------	----------
B 308	---------do-------	----------
B 313	---------do-------	----------
B 316	---------do-------	----------
B 317	---------do-------	----------
B 318	---------do-------	----------
B 345	---------do-------	----------
B 377-64	---------do-------	----------
AZ 56	---------do-------	46
BA	---------do-------	
46	Aluminum Alloys	----------
LM 8	---------do-------	----------
Birmbright B.B. 5	---------do-------	----------
Birmal P. 83	---------do-------	----------
Bohnalite	---------do-------	----------
L-4	Aluminum Alloys	----------
M-4	---------do-------	----------
W-6	---------do-------	----------
British B.S.		
1407/Nsb	---------do-------	----------
1490-LM. 24 M	---------do-------	----------
British DTD	---------do-------	----------
G 83	---------do-------	----------
G 87 A	---------do-------	----------
693	---------do-------	----------

4. Detailed Index of Specific Materials—Continued

Material	Table heading	Figure number
British DTD (cont.)		
	Aluminum Alloys	
5024	do	
5044	do	
5054	do	
5064	do	
5074	do	
Ceralium "C"	do	
Corundum	Alumina and Sapphire Crystals	64a, b, c
-Cu	Aluminum Alloys	
-Cu-Cr-Fe-Si	do	
-Cu-Fe-Mn-Si	do	
-Cu-Fe-Si	do	
-Cu-Mg	do	
-Cu-Mg-Fe-Mn-Si	do	
-Cu-Mg-Fe-Si	do	
-Cu-Mn-Fe-Si	do	
-Cu-Ni-Mg-Fe-Si	do	
-Cu-Sn-Fe-Si	do	
-Cu-Sn-Ni-Fe-Si	do	
D 132 alloy	Aluminum Alloys	
Duraluminum	do	
Duraluminum D	do	
F 132 alloy	do	
-Fe-Cu	do	
-Fe-Si-Cu	do	
Frontier 40 E	do	
Hiduminium RR 77	do	
Impalco		
740	do	
760	do	
770	do	
K-S alloy		
245	do	
280	do	
Special	do	
Kynal		
P 5	do	
P 10	do	
-Mg	Aluminum Alloys	
Nelson-Kalben	do	
Nelson-Kalben Vml	do	
Noral		
B 54 S	do	
730	do	
Rare earth-Al garnets	Rare Earth Garnets	
Ruby, artificial	Alumina and Sapphire Crystals	64a, b, c
SAE		
24	Aluminum Alloys	
25	do	
26	do	
29	do	
33	do	
35	do	
36	do	
38	do	
39	do	
201	do	
210	do	
212	do	
244	do	
245	do	
246	do	
260	do	
270	do	
280	do	
281	do	
290	do	
303	do	
304	do	
305	do	
306	do	
308	do	
309	do	
310	do	
311	do	
313 (J-453)	do	
320	do	
321	do	
322	do	
323	do	
324	do	
326	do	
329	do	
330	do	
331	do	
332	do	
380	do	
-Sb	Aluminum Semiconductor	56a
-Si-Fe	Aluminum Alloys	
Tens-50	do	
Ternalloy		
5	Aluminum Alloys	
6	do	
8	do	
Titanite	do	
y-Alloy	do	
-Zn-Cu-Fe-Si	do	
-Zn-Cu-Fe-Si-Mn	do	
40 E alloy	do	
43 alloy	do	
100 alloy	do	
108 alloy	do	
142 alloy	do	
355 alloy	do	
356 alloy	do	

4. Detailed Index of Specific Materials—Continued

Material	Table heading	Figure number
	Aluminum Alloys	
2014 alloy	---------do-------	----------
2014-T6	---------do-------	46
2219-T81	---------do-------	46
2024-T4	---------do-------	----------
3003 alloy	---------do-------	----------
4032 alloy	---------do-------	----------
5456-H 343	---------do-------	46
6061 alloy	---------do-------	----------
6063 alloy	---------do-------	----------
6101 alloy	---------do-------	----------
7039-T61	---------do-------	46
7075-T6	---------do-------	----------
Aluminum brass	Copper Alloys	----------
Aluminum bronze	Copper Alloys	----------
Aluminum-silicon bronze	Copper Alloys	----------
Alusil	Aluminum Alloys	----------
Ammonia	Ammonium Ionic and Molecular Crystals	66
Ammonium-		
NH_4Br	Ammonium Ionic and Molecular Crystals	----------
NH_4Cl	Ammonium Ionic and Molecular Crystals	66
Aniline	Miscellaneous Molecular Crystals	----------
Antimony	Antimony	31a, b
-Bi	Antimony Alloys	50
-Cd	---------do-------	50
SbSI	Antimony Ionic Crystal	62b
Sb_2Te_3	Antimony Semiconductors	----------
Sb_2Te_3-Bi_2Te_3	Antimony Semiconductors	----------
Architectural bronze	Copper Alloys	----------
Argon	Argon	35
Arsenic	Arsenic	----------
As_2Se_3	Arsenic Semiconductors	55
As_2Te_3	Arsenic Semiconductors	----------
$CdGeAs_2$	Arsenic Semiconductors	55
Barium		
-$(NO_3)_2$	Barium Ionic Crystals	----------
-F_2	Barium Ionic Crystals	61
TiO_3	Barium Ionic Crystals	61
Benzene	Miscellaneous Molecular Crystals	66
Beryll	Minerals	----------
Beryllium	Beryllium	4a, b
Beryllia	Beryllium Ionic Crystals	60a
-O	Beryllium Ionic Crystals	60a, b
Bismuth	Bismuth	31a, b
Bigg Sb_{12}	Bismuth Semiconductors	55
Hilger		
8016	Bismuth	31a
9506	---------do-------	31a
10283	---------do-------	31a
Lipowitz alloy	Bismuth Alloys	50
Rose's metal	---------do-------	50
-Sb	---------do-------	50
-Se_3	Bismuth Semiconductors	----------
-Te_3	Bismuth Semiconductors	55
Boron	Boron	23
Boron Trifluoride	Boron Ionic Crystal	----------
Brass	see Copper Materials	
Bronze	see Copper Materials	
Cadmium	Cadmium	22a, b, c, 72
Cd_3As_2	Cadmium Semiconductors	52b
-Ge As_2	Cadium Semiconductors	52b
-In S	Cadmium Semiconductors	52b
-In Se_2	Cadmium Semiconductors	52b
-In Te_2	Cadmium Semiconductors	52b
-S	Cadmium Semiconductors	52c
-Sb	Cadmium Alloys	51a
-Sb	Cadmium Semiconductors	52b
-Se	Cadmium Semiconductors	51a
-Se-Zn Te	Cadmium Semiconductors	----------
-Te	Cadmium Semiconductors	52a, c
Calcium		
-Co_3 (marble)	Calcium Ionic Crystals	----------
-F_2	Calcium Ionic Crystals	60a, b, 61
-$F_2Si_3O_{12}$	---------do-------	61
Marble	---------do-------	----------
-WO_4	---------do-------	60a
Carbon (graphite)	Carbon (Graphite)	26a, b, c, d, e

4. Detailed Index of Specific Materials—Continued

Material	Table heading	Figure number
Carbon (graphite) (cont.)		
	Carbon (Graphite)	
Acheson	---do---	---
AGOT-KC	---do---	26e, d
Allen-Bradley	---do---	26a, b
AWG	---do---	26d
Canadian natural	Carbon (Graphite)	26a
CS graphite	---do---	26e
Graph-i-tite G grade	---do---	26c
H4LM grade	---do---	26c
Lamp black	---do---	26b, c, d
Natural	---do---	26c
Natural Ceylon block	---do---	26b, e
Petroleum coke	---do---	26a
Pyrolytic	---do---	26a, b, d, e
Resin bonded graphite	---do---	26e, d
Type I Stone	Diamond	64a, c
Type II A Stone	---do---	64a
Type II B Stone	---do---	64a
Cartridge brass	Copper Alloys	---
Cerium	Cerium	36a
-Al	Cerium Alloy	---
Cerium ethylsulfate	Cerium Compounds	63a
Cerium magnesium nitrate	Cerium Ionic Crystals (very low)	75a
Cesium	Cesium	2a, b
-Br	Cesium Ionic Crystals	---
-I	---do---	---
Chromium	Chromium	11
Ferrochromium	Chromium Alloys	---
Cobalt	Cobalt	15b, 16
ALX alloy	Cobalt Alloys	---
AMS		
5537	---do---	---
5788	---do---	---
ASTM-A-399-56T	---do---	---
Co Al_2O_4	Cobalt Ionic Crystals	62b
Co Cs_3Cl_5	---do---	75
Co F_2	---do---	62a
Co (Zn) Fe_2O_4	---do---	62c
Esco alloy 72	Cobalt Alloys	---
G. E. alloy J-1570	---do---	---
Stellite alloy		
#6	Cobalt Alloys	---
#6 B	---do---	---
Nivco-10	---do---	---
Rexalloy 33	---do---	---
Tantung G	---do---	---
Umco 670	---do---	---
Unitemp L-605	---do---	---
Wallex #6	---do---	---
Constantan	Cu-Ni Alloys and Nickel Alloys	43f
Contracid	Nickel Alloys	41

Material	Table heading	Figure number
Copper	Copper	19a, b, c, 71
Admiralty metal	Copper Alloys	---
Advance	Cu-Ni Alloys	---
-Ag	Copper Alloys	---
-Al	---do---	---
-Al-Fe	---do---	---
-Al-Fe-Sn-Ni	---do---	---
-Al-Ni-Si-Fe	---do---	43c
Alpha brass	---do---	43a, c
Aluminum brass	---do---	---
Aluminum bronze	---do---	---
Aluminum-silicon bronze	Copper Alloys	---
Ambraloy		
901	Copper Alloys	---
917	Cu-Ni Alloys	---
928	Copper Alloys	---
Ampco		
15	Copper Alloys	---
metal 8	---do---	---
metal 12	---do---	---
metal 16	---do---	---
metal 18	---do---	---
metal 20	---do---	---
metal 21	---do---	---
metal 22	---do---	---
AMS		
4510	Copper Alloys	---
4520	---do---	---
4555	---do---	---
4610	---do---	---
4611 B	---do---	---
4612 C	---do---	---
4619	---do---	---
4625	---do---	---
4630	---do---	---
4630 D	---do---	---
4630 E	---do---	---
4631 C	---do---	---
4632	---do---	---
4632 B	---do---	---
4632 C	---do---	---
4635	---do---	---
4635 B	---do---	---
4640	Cu-Ni Alloys	---
4720	Copper Alloys	---
4860	---do---	---
4860 A	---do---	---
4862 B	Copper Alloys	---
Amsulf	Commercial Cu	---
Amzirc	---do---	---
Architectural bronze	Copper Alloys	---
-As	---do---	---
ASTM		
139 alloy B2	Copper Alloys	---
148 alloy 9D	Cu-Ni Alloys	---

4. Detailed Index of Specific Materials—Continued

Material	Table heading	Figure number
ASTM (cont.)		
171	Cu-Ni Alloys	
411	do	
B 14	Copper Alloys	
B 16	do	
B 19	do	
B 21-A	do	
B 21 alloy A	do	
B 21 alloy B	do	
B 21 alloy C	do	
B 30-54	do	
B 30 alloy 13 B	do	
B 36	do	
B 36 #1	do	
B 36 #2	do	
B 36 #3	do	
B 36 #4	do	
B 36 #6	do	
B 43	do	
B 62-52	Copper Alloys	
B 96	do	
B 97	do	
B 97 alloy A	do	
B 97 alloy B	do	
B 97 alloy B-12	do	
B 98 alloy B-12	do	
B 99 alloy A	do	
B 99 alloy B	do	
B 100	do	
B 103	do	
B 103-A	do	
B 105	do	
B 111	do	
B 112 alloy 2	Cu-Ni Alloys	
B 121 alloy A	Copper Alloys	
B 121 alloy 3	do	
B 121 alloy 5	do	
B 121 alloy 6	do	
B 122	Cu-Ni Alloys	
B 122 alloy 2	do	
B 122 alloy 4	do	
B 124	Copper Alloys	
B 124 #3	do	
B 124 alloy 2	do	
B 124 alloy 3	do	
B 124 alloy 4	do	
B 124 alloy 11 A	do	
B 124 alloy 11 B	Cu-Ni Alloys	
B 130	Copper Alloys	
B 134 #1	do	
B 134 #2	do	
B 134 #3	do	
B 134 #4	do	
B 134 #6	do	
B 134 #7	do	
B 135 #1	do	
B 135 #2	do	
B 135 #5	do	
B 135 alloy 3	do	
B 135 alloy 4	do	
B 138 #8	do	
B 138 alloy A	do	
B 139	Copper Alloys	
B 139-A	do	
B 139 alloy B2	do	
B 139 alloy C	Copper Alloys	
B 140 alloy B	do	
B 142-52-8A	do	
B 143-52	do	
B 144-52	do	
B 147-52-8C	do	
B 147 alloy 8A	Copper Alloys	
B 147 alloy 8A	do	
B 148	Cu-Ni Alloys	
B 148 alloy 9A	Copper Alloys	
B 148 alloy 9C	do	
B 148 GR 9B	do	
B 150	do	
B 150 alloy 1	do	
B 150 alloy 2	Cu-Ni Alloys	
B 150 alloy 3	Copper Alloys	
B 151 alloy A	Cu-Ni Alloys	
B 151-B	do	
B 159	Copper Alloys	
B 159-A	do	
B 159 alloy D	do	
B 169	do	
B 169 alloy A	do	
B 169 alloy D	do	
B 171	Cu-Ni Alloys	
B 176 alloy ZS 144 A	Copper Alloys	
B 194	do	
B 196	do	
B 197	do	
B 198 alloy 13 B	do	
B 206-B	Cu-Ni Alloys	
B 206 alloy A	do	
B 225	do	
B-265 GR. 6	do	
B 265-58 T GR. 7	do	
B 283	do	
B 301-58	Commercial Copper	
B 348	Copper Alloys	
B 395	do	
Au	do	43a
Aur-O-Met 145	do	
Avialite 915	do	
Bohnalloy R-57	do	
Be-copper	do	
Brass	do	43a, c
Bridgeport	do	
54	Copper Alloys	
712	do	
Bridgeport alloy		
77	Copper Alloys	
520	do	
British B.S.		
251	Copper Alloys	
252	do	
378	do	
409	do	
885	do	
886	do	
1464	do	
1541	do	
CABRA #405	do	
Canduloy	Cu-Ni Alloys	

4. Detailed Index of Specific Materials—Continued

Material	Table heading	Figure number
Cartridge brass	Copper Alloys	
-Cd-Fe	do	
-Cd-Fe-Si	do	
C.D.C. manganese alloy #720	Cu-Ni Alloys	
Chase 444 bronze	Copper Alloys	
Chomet bronze type A	do	
Chromium-Cu	Commercial Cu	
Commercial bronze	Copper Alloys	
Conflex 720 alloy	Cu-Ni Alloys	
Constantan	do	43f
Contact bronze	Copper Alloys	
Copper alloy #377	do	
Copper alloy #385	do	
Copper-sulphate	Cu Ionic Crystals	
Crucible A 40	Copper Alloys	
Crucible B-120 VCA	do	
Crucible C-115 A MOV	do	
Crucible C-135 AMO	do	
Cu-Au	do	
Cufenloy 30	Cu-Ni Alloys	
Cu-Mn	Copper Alloys	
Cunisil		
647	Cu-Ni Alloys	
837	do	
Cupaloy	Commercial Copper	
Cupro-nickel		
30% 707	Cu-Ni Alloys	
10% 755	do	
$Cu(NH_4)_2Br_4 \bullet 2H_2O$	Copper Ionic Crystals	75b
$Cu(NH_4)_2Cl_4 \bullet 2H_2O$	do	62b, 75a
$CuSO_4 \bullet 5H_2O$	do	75b
DHP Copper	Copper Alloys	
Duronze		
606	Copper Alloys	
609	do	
632	do	
707	do	
Eureka	Cu-Ni Alloys	
ETP copper	Commercial Copper	43b
Everdur		
655	Copper Alloys	
1010	do	
1014	do	
1015	do	
Extra-high-leaded-brass	do	
-Fe-Mg	Cu-Ni Alloys	
-Fe-Mg-C	do	
-Fe-Mg-Mn	do	
-Fe-Mn-Si-C	Copper Alloys	
-Fe-Ni-Be	do	
$-FeO_2$	Copper Alloys	
$-FeO_2S$	do	
-Fe-Pb-Zn	do	
Ferry	Cu-Ni Alloys	
-Fe-Zn	Copper Alloys	
Forging brass	do	
Free-cutting brass	do	
Free-cutting phosphor bronze	do	
Free-machining copper	Commercial Copper	
-Ge	Copper Alloys	
German silver	do	43a, c
German silver	Cu-Ni Alloys	43a
$-GeSe_3$	Copper Alloys	
Gilding brass	do	
Harvey H4-7146	Copper Alloys	
Herculoy		
420	Copper Alloys	
421	do	
High leaded brass	do	
High silicon bronze (A)	do	
Hy-Ten-Sl #1	do	
Ideal	Cu-Ni Alloys	
-In	Copper Alloys	43a
Inhibited admiralty	do	
Jewelry bronze	do	
Kentanium	do	
Leaded commercial bronze	do	
Leaded Cu	do	43b
Leaded muntz metal	do	
Leaded naval brass	do	
Leaded naval brass 605	do	
Low brass	do	
Low-leaded brass	Copper Alloys	
Low silicon bronze (B)	do	
Lumen alloy 9	do	
Lumen alloy	do	
9	do	
11-C	do	
20	do	
Lumen 97	do	
Magnet wire	Commercial Cu	43e
Mallory-3	do	
Mallory 53B	do	
Mallory 100	Copper Alloys	
Manganin	do	43a
Manganine	do	
Manganese bronze	do	
Medium-leaded brass	do	
Midohm	Cu-Ni Alloys	
MIL-		
B-895	Copper Alloys	
B-6946	do	
B-159 39 comp. 5	do	
B-160 33 class 1	do	
B-212 30 A	Cu-Ni Alloys	
C-175 16 comp. #2	Copper Alloys	
C-19311	Commercial Cu	
-Mn-Fe	Copper Alloys	
-Mn-Fe-Mg	do	
-Mn-Fe-Mg-C	do	
MST		
431	Copper Alloys	
4 Al-4 Mn	do	
5 Al-2.5 Sn	do	
7 Al-4 Mo	do	
8 Mn	do	
Mueller 515	Cu-Ni Alloys	
Mueller 803	Copper Alloys	
Mueller brass alloy 799	Commercial Cu	
Muntz metal	Copper Alloys	
Naval brass	do	
Navy "M"	do	
Neusilber	Cu-Ni Alloys	
Neusilber	Copper Alloys	43a
Nialite	Cu-Ni Alloys	
Ni-Bral	do	

4. Detailed Index of Specific Materials—Continued

Material	Table heading	Figure number
Nickel silver		
65-12+55-18	Cu-Ni Alloys	
65-18	do	
Nicuite	do	
Nironze 635	do	
Noranda-3770	Copper Alloys	
OFHC	Commercial Cu	43b
Olin 605	Copper Alloys	
-P	do	
-Pb-Sn-Ni-P	do	
-Pb-Zn	do	43c
-Pd	Copper Alloys	43a
Phosphor bronze	do	43c
Phosphor bronze alloy		
A	Copper Alloys	
C	do	
D	do	
E	do	
Platinoid	Cu-Ni Alloys	43a
Platinoid	Copper Alloys	43a, c
Red brass	do	
Rem-Cru		
A-55	do	
A-70	do	
A-110 AT	do	
C-110 M	do	
120 AV	do	
135 A Mo	do	
Republic		
RS 110-A	Copper Alloys	
RS 110-C	do	
RS 130	do	
RS 135	do	
Resistae #1	do	
Revere		
140	Copper Alloys	
240	do	
429	do	
430	do	
454	do	
508	Commercial Cu	
533	do	
575	do	
770	do	
alloy 2	Copper Alloys	
alloy 411	do	
Riverside		
4	Commercial Cu	
105	Copper Alloys	
R.W.M.A Gr. A		
class 2	Commercial Cu	
SAE		
43	Copper Alloys	
68 A	Cu-Ni Alloys	
68 A Gr. A cast	Copper Alloys	
68 Gr. B	do	
70 A	do	
72	do	
73	do	
74	do	
74 C	do	
74 D	do	
77	do	
79 A	do	
SAE (cont.)		
79 B	Copper Alloys	
80 A	Copper Alloys	
81	do	
88	do	
430 B	do	
701	Cu-Ni Alloys	
701 B	Copper Alloys	
791	do	
7018	do	
Scobronze	do	
-$SbSe_2$	Cu Semiconductors	56a
-Sb-Sn	do	56a
Seymour		
12 A 1	Cu-Ni Alloys	
910	Copper Alloys	
928	do	
950	do	
9494	do	
-Si-Fe	Cu-Ni Alloys	
-Si-Fe	Copper Alloys	
-Si-Mn-Fe	do	
-Si-Zn-Fe	do	
Silber bronze	do	43a
Silicon bronze	do	43b
-Sn	do	
-$Sn-Se_3$	Cu Semiconductors	56a
-Sn-Zn-Fe	Copper Alloys	
Superston 40	Cu-Ni Alloys	
Tellurium copper	Commercial Cu	
-Ti-4Al-3Mo-1V	Copper Alloys	
-Ti-5Al-2.5Sn	do	
-Ti-7Al-4Mo	do	
-Ti-8Al-1Mo-1V	do	
-Ti-155 A	do	
-Ti-6Ar-6V-2Sn	do	
-Ti-2Fe-2Cr-3Al	do	
-Ti-8Mn	do	
-Ti-O-15Pd	do	
-Ti-13V-11Cr-3Al	do	
Tuf-Stuf		
224 C	Copper Alloys	
224 E-75	do	
224 H	do	
224 K	do	
Tobin bronze 452	do	
Tombasil	do	
Wearite 4-13	do	
Yellow brass	do	
-Zn	do	43b
-Zn-Al-Fe	do	
-Zn-Al-Mn-Fe	do	
-Zn-Fe	do	
-Zn-Fe	Cu-Ni Alloys	
-Zn-Fe-Mn-C	do	
-Zn-Fe-Sn-Pb-Mn	Copper Alloys	
-Zn-Ni-Mn-Fe	do	
-Zn-Ni-Mn-Fe-C	do	
-Zn-Ni-Mn-Fe-Mg	do	
-Zn-Ni-Pb-Sn-Fe	do	
-Zn-Pb-Fe	do	
-Zn-Pb-Fe-S	do	
-Zn-Pb-Sn-Mn-Fe	Cu-Ni Alloys	
-Zn-Si-Mn-Fe	Copper Alloys	
-Zn-Sn-Fe-Mn-Al	do	
-Zn-Sn-Pb-Fe	do	
-Zn-Sn-Pb-Fe-Al-Si	do	
-Zn-Sn-Pb-Fe-P	do	

4. Detailed Index of Specific Materials—Continued

Material	Table heading	Figure number
Corundum	Alumina and Sapphire Crystals	64a, b, c
Cupro-nickel	Cu-Ni Alloys	----------
Diamond	Diamond	64a, c
Type I stone	---------do-------	64a, c
Type IIa stone	---------do-------	64a
Type IIb stone	---------do-------	64a
Diphenylamine	Miscellaneous Molecular Crystals	----------
Dowmetal	Magnesium Alloys	----------
Dural	Aluminum Alloys	----------
Dysprosium	Dysprosium	36a, b
Dysprosium-Al garnet	Rare Earth Garnets	----------
Easy-flo	Silver Alloys	44a
Epibond	Polymers	76
Erbium	Erbium	36b, 38
Erbium-Al garnet	Rare Earth Garnets	----------
Eureka	Cu-Ni Alloys	----------
Europium		
-O	Europium Compound	63a
Everdur	Copper Alloys	----------
Ferrosilicon	Silicon Alloys	----------
Gadolinium	Gadolinium	36b, 37
Gadolinium-Al garnet	Rare Earth Garnets	----------
Gallium	Gallium	25a, b, 73
-As	Gallium Semiconductors	53a, b, c, d
Ga P	Gallium Semiconductors	53a, c
-Sb	Gallium Semiconductors	53b, c, d
Garnets	Rare Earth Garnets	----------
Germanium	Germanium	28a, b, c, d, 74
$-O_2$	Germanium Ionic Crystals	62b
German silver	Copper Alloys and Cu-Ni Alloys	43a, c
Glass		
Crown glass	Disorder Dielectrics	67b
Fotoceram	---------do-------	67b
Glass S49-2	---------do-------	67a
J16 III	---------do-------	67b
Jena 16 III	---------do-------	67b
Jena gerate 20 glass	---------do-------	67b
Monax	---------do-------	67b
Phoenix	---------do-------	67a
Porcelain	---------do-------	67a
Pyrex	---------do-------	76
7740 Pyrex	---------do-------	67a
Pyroceram	---------do-------	67b
Quartz	---------do-------	67a
Silica	---------do-------	67b
SiO_2 glass	---------do-------	67a, 76
Soda lime glass	---------do-------	67b
Thuringian glass	---------do-------	----------
Glycerine	Miscellaneous Molecular Crystals	----------
Gold	Gold	20b, 21, 71
-Ag	Gold Alloys	45a
-Cd	---------do-------	----------
-Cn	---------do-------	45
-Co	---------do-------	45b
-Cu	---------do-------	45a
-Fe	---------do-------	45a, b
-Pd	---------do-------	45a
-Pt	---------do-------	45a
-Sn	---------do-------	45a, b
-Zn	---------do-------	----------
Grease	Polymers	68c
Grossularite	Minerals	63b
Hafnium	Hafnium	7
-Ta	Hafnium Alloys	----------
Hastelloy	Nickel Alloys	41
Helium	Helium	34a, b, c, d
Hessonite	Minerals	63b
Holmium	Holmium	36b, 38, 74
-Al	Holmium Compounds	----------
$-(C_2H_5SO_4)_3 \bullet 9H_2O$	---------do-------	63a
Hydrogen	Hydrogen	1
Illium	Nickel Alloys	----------
Inconel	---------do-------	----------
Indium	Indium	25a, b, 73
-As	Indium Semiconductors	53b
-Bi	Indium Alloys	----------
-Ga-Sb	Indium Semiconductors	53c
-P	---------do-------	53c, d
-Pb	Indium Alloys	47
-Sb	Indium Semiconductors	53a, b, c, d
-Sn	Indium Alloys	47
$-Te_3$	Indium Semiconductors	----------
-Tl	Indium Alloys	47, 75a, b
Iridium	Iridium	18a, b
Iron	Iron	15a, b, 69
AISI		
94 B30	Alloy Steels	----------
301	Stainless Steels	----------
303	---------do-------	40a
304	---------do-------	40a
316	---------do-------	40a
325	---------do-------	----------
330	---------do-------	----------
347	---------do-------	----------
410	---------do-------	----------
416	---------do-------	----------
443	---------do-------	----------
2330	Alloy Steels	----------
3120	---------do-------	----------
3130	---------do-------	----------
3140	---------do-------	----------
3150	---------do-------	----------
4023	---------do-------	----------
4340	---------do-------	----------
4422	---------do-------	----------
4615	---------do-------	----------
5140	---------do-------	----------
5150	---------do-------	----------
6145	---------do-------	----------
6150	---------do-------	----------
6170	---------do-------	----------
8630	---------do-------	----------
8735	---------do-------	----------
8740	---------do-------	----------
8742	---------do-------	----------
9440	---------do-------	----------
9840	---------do-------	----------
AMS 6302	---------do-------	----------
-Al-Si-Mn-C-S	---------do-------	40b
Allegheny		
42	Iron Alloys	40b
88y	Alloy Steels	----------
Alloy 300 M	---------do-------	----------
Armco iron	Iron	15a
ASTM		
322	Alloy Steels	----------
A 157-44	---------do-------	----------
A 182	Stainless Steels	----------
A 193-52T	Alloy Steels	----------
A 223	Stainless Steels	----------
A 268	---------do-------	----------
A 274	Alloy Steels	----------
A 296	Stainless Steels	----------

4. Detailed Index of Specific Materials—Continued

Material	Table heading	Figure number
Iron (cont.)		
A 304	Alloy Steels	
A 322	do	
A 331	do	
A 351	Stainless Steels	
Atlar CM	Alloy Steels	
Austenitic steel	Stainless Steels	40a
Bethlehem #7	Iron Alloys	
Boron stainless steel	Stainless Steels	
-C-Si-Mn-Cu-P-S	Carbon Steels and Cast Iron	
-C-Si-Mn-S-P	Carbon Steels and Cast Iron	
Carpenter high permeability 49	Iron Alloys	
Carpenter stainless #3	Stainless Steels	
#20	do	
Carpenter 42	Iron Alloys	
709	Alloy Steels	
Cascade	do	
Ceramovar	Iron Alloys	
Chatillon 709	Alloy Steels	
Colhead	Carbon Steels and Cast Iron	
Cooper alloy 145	Stainless Steels	
-Co (Zn) Fe_2O_2	Iron Ionic Crystals	62c
-Cr	Stainless Steels	40b
Cronax	do	
Cyclops 17 B	do	
D-H #42	Iron Alloys	
Donegal D-28	Stainless Steels	
Ductalloy	Carbon Steels and Cast Iron	
Duralloy H T	Stainless Steels	
Duramold B	Alloy Steels	
Durehete 900	do	
Durehete 950	do	
Dynaflex	do	
En 31	do	
ERA/ATV	Iron Alloys	40a
Esco-12m	Alloy Steels	
Fe Al_2O_4	Iron Ionic Crystals	
FeO_4	do	
$Fe \bullet 5Zn \bullet 5Fe_2O_4$	do	
Ferro-chromium	Iron Alloys	
Ferro-manganese	do	
Ferro-silicon	do	
Ferrovac 4340	Alloy Steels	
Firth-Vicker FV 520	Stainless Steels	
FV 520 B	do	
326	do	
448	do	
French AFNOR 18 CDV 4	Alloy Steels	
Hardtem	do	
Hecla	do	
Heppenstall T 73	Alloy Steels	
5 H 50	do	
6 H 55	do	
Hi Qua-Led 43L40	do	
Hiperco 27	Iron Alloys	
Hotpure	Alloy Steels	
HWD #1	Alloy Steels	
#2	do	
Hy-Tem "B" temper #2	do	
#3-x	do	
Impacto	do	
Jessop #200	Alloy Steels	
Kanthal-A	Stainless Steels	
Kovar "A"	Iron Alloys	
Latrobe C. L. W.	Alloy Steels	
Lominium	do	
Macloy G steel	Iron Alloys	
Malleable iron	Carbon Steels and Cast Iron	
Manganese steel	Alloy Steels	40a
Meehanite GE	Carbon Steels and Cast Iron	
HR	Carbon Steels and Cast Iron	
Mild steel	Carbon Steels and Cast Iron	40c
10-Mn-Al_4	Carbon Steels and Cast Iron	
-Mn-C-Si	Alloy Steels	40b
-$MnFe_2O_4$	Stainless Steels	
-Mn-Ni-Si	Carbon Steels and Cast Iron	
-Mn-Si-S-C-P	Alloy Steels	40b
-Ni	Iron Alloys	40a, c
-Ni-Mo	Alloy Steels	40b
Ni-resist	do	
Ni-resist	Carbon Steels and Cast Iron	
Ni-resist ductile iron	Alloy Steels	
Ni-resist ductile iron	Carbon Steels and Cast Iron	
Nilo K	Iron Alloys	
Orion	Alloy Steels	
OSRM iron 1265	Iron	15a
Peerless	Alloy Steels	
Potomac A	do	
Pressurdie 2	do	
Rodar	do	
SAE 1010	Carbon Steels and Cast Iron	40c
1020	Carbon Steels and Cast Iron	40c
1095	Carbon Steels and Cast Iron	40c
3130	Alloy Steels	
4130	do	40c
5141 6F	Stainless Steels	
8630	Alloy Steels	
8740	do	
9840	do	
Sandvik 11 R 51	Stainless Steels	
Seneco hot die	Alloy Steels	
-Si	Iron Alloys	40b
Silicrome-RA	Stainless Steels	
Silver steel	Carbon Steels and Cast Iron	40c
Speed alloy	Alloy Steels	
TT St. 35	Carbon Steels and Cast Iron	40c
45	Carbon Steels and Cast Iron	40c
T-loy 34	Alloy Steels	
Thermold 422	do	
Timang	do	
Timkem	do	
HS-260	Alloy Steels	
4419	do	
Tricent	do	

4. Detailed Index of Specific Materials—Continued

Material	Table heading	Figure number
Type		
10 Ni 14	Alloy Steels	40b
12 Ni 19	---do---	40b
12870	---do---	40b
1287 I	---do---	40b
1798 H	---do---	40b
X 8 Ni 9	---do---	40b
X 40 Mn Cr 42	---do---	
3703	Alloy Steels	40b
3754	Stainless Steels	40a
Unitemp-14MV	Alloy Steels	
Uniloy 1420 WM	---do---	
Vanadium type "D"	---do---	
Westinghouse W 545	Stainless Steels	
Wrought iron	Iron	15a
Wrought iron	Carbon Steels and Cast Iron	
X 5-Cr-Ni-18-9	Stainless Steels	
X 8-Cr-Ni-Mo-Nb-16-16	---do---	
X 8-Cr-Ni-Nb-16-13	---do---	
X 10-Cr-Ni-Mo-Ti-18-10	---do---	
10-Mn-Al_4	Carbon Steels and Cast Iron	
Krypton	Krypton	35
Lanthanum	Lanthanum	5a, b
LMN (lanthanum magnesium nitrate)	Miscellaneous Alloys (very low T)	
-S	Lanthanum Semimetals	56b
-Sb	---do---	56a
-Se	---do---	56b
-Te	---do---	56b
Lead	Lead	29a, 30a, b, 74
-Bi	Lead Alloys	48b, 49
-In	---do---	48b, 49
-S	Lead Semiconductors	54
-Sb	Lead Alloys	
-Sb-Sn	---do---	
-Se	Lead Semiconductors	54
-Sn	Lead Alloys	49
Tadanac	Lead	29a, 30a, b
-Te	Lead Semiconductors	54
Lipowitz alloy	Bismuth Alloys	50
Lithium	Lithium	2a, b
-F	Lithium Semiconductors	56a
-F	Lithium Ionic Crystals	57a, b, c, 75a
-NbO_3	Lithium Ionic Crystals	57b
Lucite	Polymers	68c
Lutetium	Lutetium	36b, 38
Lutetium-Al garnet	Rare Earth Garnets	
Magnesium	Magnesium	4a, b
Al_2O_4	Magnesium Ionic Crystals	61
AM-C 595	Magnesium Alloys	
ASTM		
A 8	Magnesium Alloys	
A 10	---do---	
AM 80 A	---do---	
AZ 31 X, A, B	---do---	
AZ 80 X, A	---do---	
AZ 81 A (T4)	---do---	
AZ 91 A, B, C	---do---	
AZ 92, A	---do---	
EK 30 A	---do---	
HK 31 A	---do---	
Magnesium (cont.)		
HM 11 X A	Magnesium Alloys	
HM 21 A	---do---	
HM 31 A	---do---	
HZ 32 A	---do---	
MI A, B	---do---	
MSR-A	---do---	
ZE 41 A	---do---	
ZH 42	---do---	
ZH 62 A	---do---	
ZK 21 A	---do---	
ZK 41 A	---do---	
63, A	---do---	
100 A	---do---	
British DTD		
59 A	Magnesium Alloys	
88 B	---do---	
118	---do---	
120 A	Magnesium Alloys	
136 A	---do---	
140 A	---do---	
142	---do---	
259	---do---	
289	---do---	
5025	---do---	
British RZ 5	---do---	
Dowmetal		
A	---do---	
C	---do---	
EK 30 A	---do---	
EK 41 A	---do---	
EZ 33 A	---do---	
FS-1	---do---	
H	---do---	
HK 31 X A	---do---	
HZ 32 X A	---do---	
M	---do---	
O-1	---do---	
R, RC	---do---	
6	---do---	
Eclipsaloy		
130	Magnesium Alloys	
517	---do---	
Elektron		
A8, A8K	Magnesium Alloys	
AM 503	---do---	
AZG	---do---	
AZM	---do---	
AZ 91	---do---	
AZ 855	---do---	
MCZ	---do---	
TZ 6	---do---	
ZER O	---do---	
ZRE 1	---do---	
ZT 1	---do---	
ZW 3	---do---	
Z5Z	---do---	
VI	---do---	
-$FeAl_2O_4$	Magnesium Ionic Crystals	61
Flylite ZRE-1	Magnesium Alloys	
Ge	Magnesium Semiconductors	56a
Mazlo		
AM-C 52S	Magnesium Alloys	
AM-C 58S	---do---	
AM 35	---do---	
AM 240	---do---	
AM 241	---do---	
AM 244	---do---	
AM 260	---do---	

4. Detailed Index of Specific Materials—Continued

Material	Table heading	Figure number
Mazlo (cont.)		
AM 263	Magnesium Alloys	----------
AM 265	---------do-------	----------
AM 403	---------do-------	----------
Mg-Ag	---------do-------	----------
Mg-Al	---------do-------	----------
Mg-Al-Cd-Sn	---------do-------	----------
Mg-Al-Zn-Cd-Sn	---------do-------	----------
Mg-Al-Zn-Cu	---------do-------	----------
Mg-Ce	---------do-------	----------
Mg-Cu	---------do-------	----------
Mg-Cu-Si	---------do-------	----------
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FORM NBS-114A (1-71)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBS-MONOGR-131	2. Gov't Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE

Thermal Conductivity of Solids at Room Temperature and Below. A Review and Compilation of the Literature

5. Publication Date

September 1973

6. Performing Organization Code

7. AUTHOR(S)

Gregg E. Childs, Lewis J. Ericks, Robert L. Powell

8. Performing Organization

9. PERFORMING ORGANIZATION NAME AND ADDRESS

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

10. Project/Task/Work Unit No.

2750101

11. Contract/Grant No.

12. Sponsoring Organization Name and Address

Same as Item 9.

13. Type of Report & Period Covered

Final

14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)

An extensive compilation is given of the measured values of thermal conductivity for nearly all solid materials from room temperature down to 0.01 Kelvin. The reviewed materials include elements, alloys and commercial metals, semiconductors, semimetals, ionic and valence crystals, minerals, molecular crystals, polymers, glasses, and disordered dielectrics. Excluded are foams, powders, earths, fibers, layers of composites, and similar other heterogeneous solids. Data for temperatures below 1 kelvin are presented separtely. The tables and graphs are complete for literature references from 1900 to mid-1971. Experimental methods and physical phenomena are discussed in the text and coded in the tables for references for which curves are shown.

17. KEY WORDS (Alphabetical order, separated by semicolons) Cryogenic thermal conductivity; elements, alloys, commercial metals, semiconductors, semimetals, ionic and valence crystals, minerals, molecular crystals, polymers, glasses, disordered dielectrics, thermal conductivity of; review; thermal conductivity.

18. AVAILABILITY STATEMENT

[X] UNLIMITED.

[ ] FOR OFFICIAL DISTRIBUTION. DO NOT RELEASE TO NTIS.

19. SECURITY CLASS (THIS REPORT)

UNCLASSIFIED

21. NO. OF PAGES

624

20. SECURITY CLASS (THIS PAGE)

UNCLASSIFIED

22. Price

$7.80

☆ U.S. GOVERNMENT PRINTING OFFICE: 1973 O—489-527

USCOMM-DC 66244-P71

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (Order by SD Catalog No. C13.44:131). Price: $7.80, domestic postpaid; $7.25, GPO Bookstore